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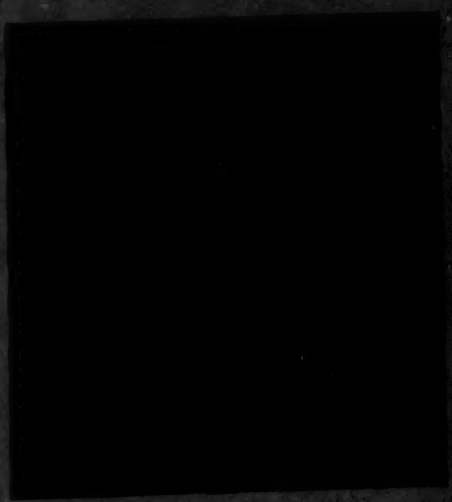

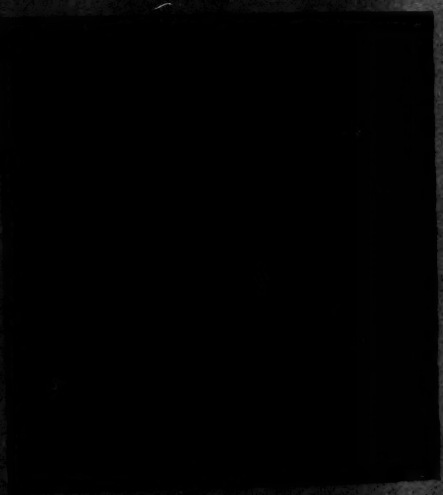

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OF

OPHTHALMOLOGY

APRIL, 1950

COMMUNICATIONS

THE POLARIZATION OPTICS OF THE ISOLATED CORNEA*

BY

A. STANWORTH AND E. J. NAYLOR

Manchester

IT has long been known that the cornea, like most biological tissues, changes polarized light passing through it, but the possibility that these changes vary with the intra-ocular pressure (Stanworth, 1949) justifies a further examination of the subject.

Previous Studies of the Isolated Cornea

Brewster (1815) was the first to report that the cornea was anisotropic, but the first adequate study was that of Valentin (1861), who found that when the cornea was placed between a polarizer and crossed analyser a dark cross-shaped figure with peripheral concentric coloured bands was produced. A figure similar to this is also seen when convergent light is incident on a uniaxial crystal plate cut perpendicular to the optic axis, *i.e.*, perpendicular to the direction along which no double refraction

* Received for publication August 6, 1949.

takes place. Valentin therefore postulated that the cornea behaves as a curved uniaxial crystal plate with the optic axis at any point always perpendicular to the plane of the cornea.

His (1856) found, on the other hand, that when sections of the cornea were examined in polarized light the corneal lamellae were doubly refracting with the optic axis along their length, and therefore in the plane of the cornea. In view of this, Valentin's conclusions seemed unlikely, and Rollett (1871) pointed out that the shape of the interference figure could be explained if the corneal lamellae, having an optic axis along their length, were arranged in a predominantly radial manner. Since, however, there was no anatomical evidence of such a radial arrangement, the explanation was not entirely satisfactory.

Fleischl (1880) also studied the interference figure, and came to the conclusion that it was seen only when the cornea was under tension, the unstretched cornea showing no double refraction. That this is not the case was shown by Schiötz (1882), using calves' and pigs' eyes. He devised a pressure chamber in which the excised cornea was supported by pins passing through adjacent sclera: pressure could then be applied to the posterior surface of the cornea by filling the chamber with saline and connecting it to a manometer. He found that when the applied pressure approximated to the normal intra-ocular pressure, a well-defined interference figure could be produced, though the clarity of the figure did increase when the pressure was raised. He also found that the interference figure was not a simple cross except when the polarizer and analyser were parallel to two mutually perpendicular directions in the cornea. In all other positions of the polarizer and analyser, the cross was replaced by hyperbolas.

These investigators made no attempt to measure the magnitude of the birefringence of the cornea. Nordenson (1921) did make such measurements, using mainly the method of estimating the birefringence by noting the colour of the tissue observed in the polarizing microscope and comparing it with the Michel-Levy colour chart. Estimates of colours are, however, notoriously subjective and the method is only an approximate one, although Nordenson did check some of his results by using a Berek compensator. A more serious objection is that his measurements were not made under physiological conditions, and, as we shall show, the position in the cornea at which the measurements are made, and the direction of the incident and emergent light, are of considerable importance.

Cogan (1941) noted that an interference figure could be seen in the living eye in polarized light, and briefly reviewed the literature on the figure in the isolated cornea. He was unable to put forward any adequate theory to explain its presence.

Present Investigations

In order to study the birefringence of the isolated cornea adequately a method of suspension is required which maintains it in as physiological a condition as possible. The pressure chamber shown in Fig. 1 was used. It consists, in principle, of two chambers between which the isolated fresh cornea is suspended by clamping an attached rim of sclera between two roughened surfaces (R), of such radii that the sclera fits perfectly to form a

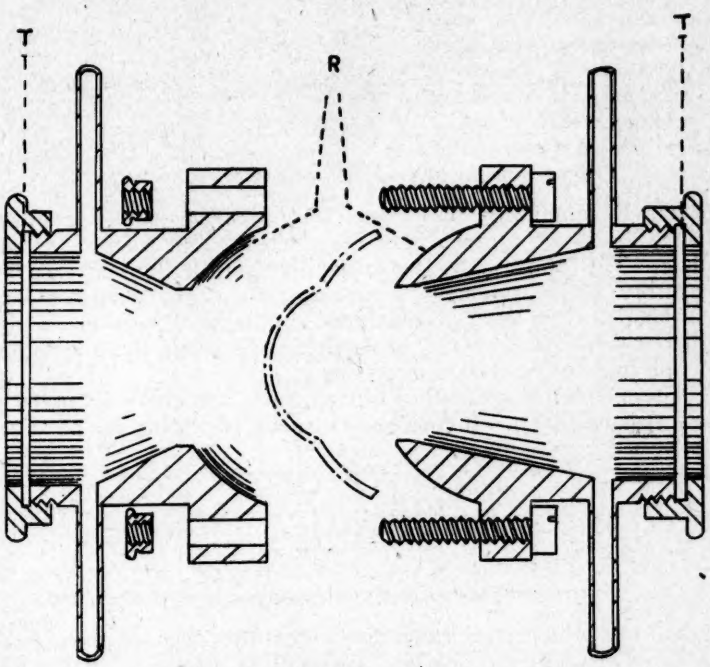

FIG. 1.—Pressure chamber.

watertight joint. The chambers are closed at the front and back of the apparatus by strain-free glass plates (T), and can be filled with any required fluid at any desired pressure. In order to maintain physiological conditions as far as possible, Ringer's solution is used, at a pressure in the posterior chamber of about 20 mm. Hg. The anterior chamber is filled with this solution at atmospheric pressure, and so fulfils the double function of keeping the anterior surface of the cornea moist and minimizing its refractive effect.

The optical arrangement for studying the cornea as a whole is shown in Fig. 2. The light from a slit lamp source (S) is collimated by the lens (L), passes through a polarizer (P), and then through the specimen, which is observed through the analyzer (A). The polarizer and analyser are rotatable and their positions can be measured by means of verniers.

For measurements of the birefringence, the arrangement in Fig. 3 was used. The additional apparatus is a pinhole (D), a low-power—2 in.—objective (O), a quarter-wave plate (W), and an

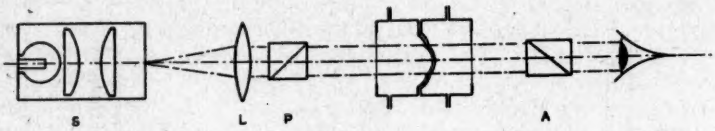

FIG. 2.—Arrangement of apparatus for studying the cornea.

ocular (E) containing cross wires. Two auxiliary items not shown in the figure are a green filter (Wratten 62) and a sensitive tint plate. The former is inserted in the light path (LP) to increase the accuracy of measurement by making the light almost monochromatic. The latter is substituted, in diagonal position, for the quarter-wave plate when it is required to ascertain the orientation of the principal vibration directions.

The method of measuring birefringence was that of Goranson and Adams (1933). It consists essentially of placing the polarizer

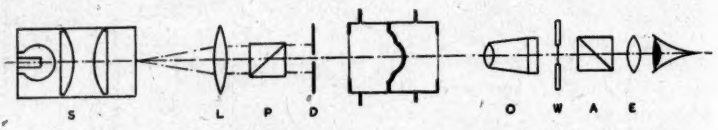

FIG. 3.—Arrangement of apparatus for measurements of the birefringence.

at 45° to a principal vibration direction of the specimen at the point to be measured; the quarter-wave plate is placed parallel to the polarizer and the analyser is then rotated until the light is extinguished. The retardation in degrees is then twice the angle the analyser makes with its original " crossed " position, measurements being made either clockwise or anti-clockwise according to the relative orientation of the principal vibration directions of the specimen and the quarter-wave plate.

Results

The general appearance of the cornea between a polarizer and a crossed analyser is that described by previous authors, and is

shown for the cat cornea in Fig. 4. The interference figure is made up of two parts, one consisting of a series of roughly circular concentric coloured rings or bands, the other of a dark cross-shaped figure. The former are bands connecting points of equal retardation, the magnitude of which determines the colour, and by analogy with photo-electric stress patterns and crystal optics can be termed "isochromatics". Similarly, the dark bands are analagous to "isogyres" or "isoclinics", and connect points at which the principal vibration directions of the cornea coincide with the directions of the polarizer and analyser. The dark bands form an almost perfect cross for all positions of the polarizer and crossed analyser, though when they are examined carefully, they can usually be resolved into two rectangular hyperbolas, with only a

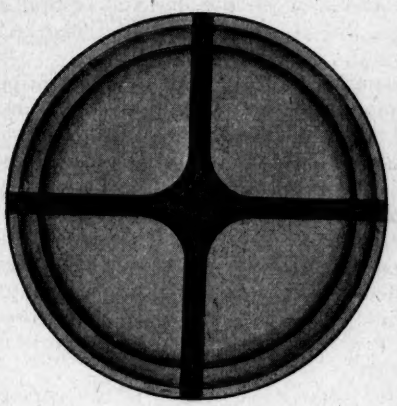

FIG. 4.—Interference figure of the cat cornea.

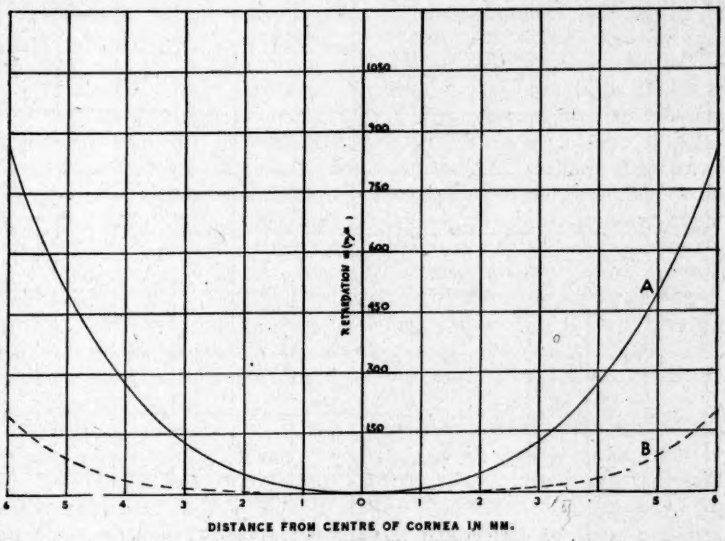

FIG. 5.—Measurements of the retardation at various distances from the centre of the cornea.

slight separation between them. In the human, dog, and rabbit corneas the isogyres are almost identical with those in the cat, but in the ox and sheep corneas, a marked separation of the hyperbolas is seen. In general the cross-shaped isogyres in the human and cat cornea are equivalent to those seen when a uniaxial crystal is examined in convergent light, the hyperbolic type of isogyres corresponding to a biaxial crystal.

The colours of the isochromatics indicate that the retardation increases from a very small value in the optical zone of the cornea to a maximum (in the cat) of about 2 wave-lengths retardation at the periphery. This is also seen in Fig. 5, A which shows the retardation at various distances from the centre of the cornea, measured by the method described above. This does not, however, indicate that the essential birefringence of the corneal substance at the periphery is necessarily greater than in the centre, as the light passing through the periphery is traversing a much greater thickness of the cornea. This is due not only to the increased peripheral thickness but also to the gradually increasing angle at which the light meets the cornea.

In fact, measurements of the retardation normal to the surface of the cornea (Fig. 5, B) indicate that the retardation in the whole of the optical zone is very small, and it can be calculated from these results that the effective birefringence of the cornea, expressed as

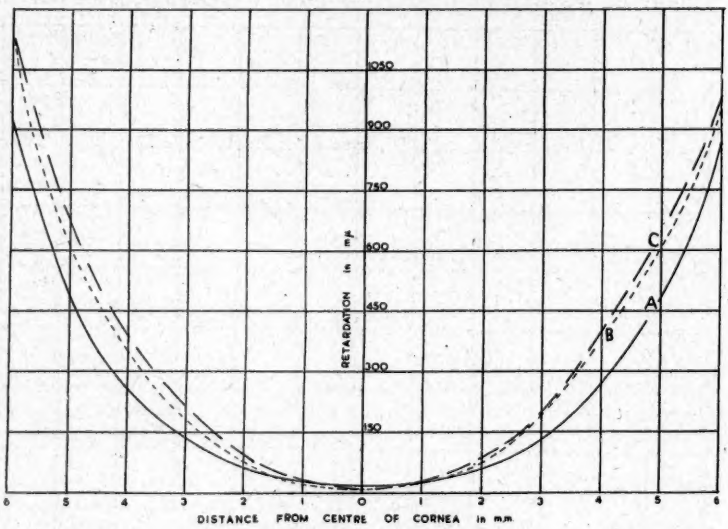

FIG. 6.—Effects of 3% formalin on the original retardation.

the difference between the ordinary and extraordinary refractive indices, varies from zero in the centre to about 0·00012 at the edge of the optical zone, and, allowing for the increased thickness, to about 0·00027 at the extreme periphery. Unfortunately it was not possible to reach the periphery of the cornea using the physiological method of suspension described above: measurements at the periphery could only be done by using a cornea fixed in formalin, which retains its shape when the attached scleral rim is pinned on to a cork ring mounted on a microscope slide. It is from measurements made on such corneas that the values of the retardation in Fig. 5, B for points on the cornea more than 3 mm. from the centre are derived. That this procedure gives readings approximating to those of the normal cornea is seen from Fig. 6, which shows the effects on the original retardation (A) of 3 per cent. formalin in the apparatus for one day (B) and six days (C).

Discussion

Since His (1856) has shown from the study of sections that the most important birefringent elements of the cornea are the lamellae, the interference figure must obviously be explained in terms of these lamellae, the distribution of which must result in the observed shape of the isogyres and a total birefringence such as described above.

That the retardation produced by the cornea is so small can be explained by a consideration of the summation of the effects of numerous superimposed layers of lamellae lying in different directions. If two lamellae of equal retardation are situated at right angles, there will be no retardation for light passing perpendicular to the plane in which they lie, as the retardation produced by one will cancel that produced by the other. Consequently the small retardation for light normal to the cornea could be produced either by a random arrangement of the lamellae, or by lamellae running in alternating layers at approximately right angles, such as described by Virchow (1910). Nevertheless, provided that this is the total effect, such arrangements are not excluded as that described by Kokott (1938) wherein the superficial layers are predominantly vertical, the middle layers running mainly in directions corresponding to the insertions of the recti, and the deep layers showing predominantly circular fibres in the periphery.

We have already noted that Nordenson (1921) also found the birefringence of the cornea to be low, and he gave a mean value of 0·00059 with only a small variation from this figure. This is much higher than we have found, probably because Nordenson used an excised piece of cornea spread on a glass sphere; also it is not certain that all his measurements were made normal to the cornea.

Nordenson concluded from this low value for the birefringence that it was of little importance during normal use of the eyes. Boehm (1940), however, as a result of observations on the effect of crystal plates of various retardations on the entoptic phenomenon of Haidinger's brushes in blue light, concluded that the ocular media produced in some way the effect of approximately a one-eighth-wave plate (a retardation of about 50 mμ). He thought that this effect was probably due to the cornea and that the lens was excluded as the source of the phenomenon by the fact that the latter was still present in aphakia. It appears unlikely, however, in view of our results, that the cornea could have an effect of this magnitude; nevertheless, owing to the angle between the fixation and the optic axes, the macula is not quite symmetrically placed with regard to the cornea, and some slight retardation might be produced by the obliquity of the rays reaching the fovea. The same mechanism might also produce an additional retardation due to birefringence of the lens, which together with that due to the cornea, might amount to the magnitude suggested by Boehm. In that case the persistence of this retardation after the removal of the lens may be due to post-operative astigmatism of the cornea, which may well, as we shall see, convert the cornea from a uniaxial to a biaxial type and hence produce the observed retardation.

The isogyres have given rise to some speculation and have usually been considered to give an indication of the fibre directions in the cornea. Their appearance with various positions of the polarizer and crossed analyser, however, leads essentially to a determination of the principal vibration directions (Figs 7 and 8). Fig. 7, which corresponds to the cross-shaped isogyres,

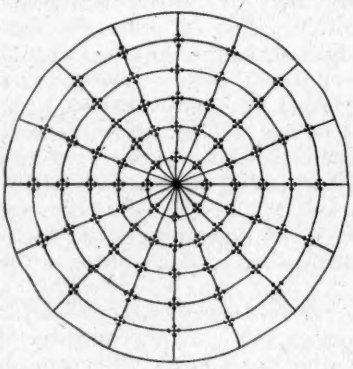

FIG. 7.—Vibration directions in the cornea corresponding to cross-shaped isogyres.

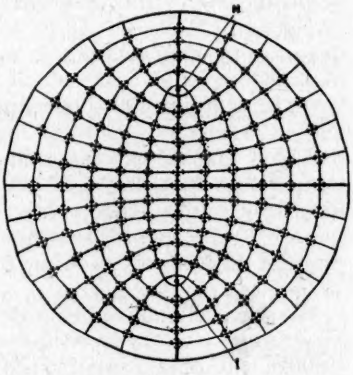

FIG. 8.—Vibration directions in the cornea corresponding to hyperbolic isogyres.

shows that at any point the principal vibration directions are radial and perpendicular to the radius, and this, as we have seen, has led to the supposition that the lamellae must run predominantly radially (Rollett, 1871). For the hyperbolic figure, on the other hand, the principal vibration directions are as shown in Fig. 8, the distance between points H and I being a measure of the separation of the hyperbolas. A figure somewhat similar to this, evolved by Schiötz (1882), suffers from the defect that at some places three lines pass through the same point: he too identified these as the possible directions of the birefringent elements, which he thought to be probably the lamellae.

It is not necessary, however, to interpret these diagrams as indicating the directions of the lamellae. If a ray of light passes at an angle through a combination of two lamellae at right angles, such as described above, the retardation produced will not in general be zero, and the principal vibration directions of the cornea for such a ray of light will be in the plane of incidence of the ray and perpendicular to this plane. Owing to the curvature of the cornea, rays of parallel light meet the cornea in such a way that the plane of incidence is always radial to the cornea, and hence, if the cornea is examined in plane polarized light, the principal vibration directions must always be radial and perpendicular to the radius. The cross-shaped isogyres are thus explained without any preferential arrangement of lamellar directions.

If this be the case, it is easy to understand why a rise in pressure in the posterior chamber of the suspension apparatus fails, as Schiötz observed, to alter the shape of the isogyres, for however much it may alter the birefringence of the individual lamellae (Stanworth, 1949), the combination will still produce zero retardation for light passing normal to the cornea, and hence will give rise to a cross-shaped figure in the same manner as that already described. A change in the birefringence of the individual lamellae could only be detected by using rays of light passing through the cornea at a large angle, so that they were affected more by some lamellae than by others, thus making an approach to isolating lamellae running in one direction only.

In the case of the hyperbolic isogyres additional factors must be involved. It may be of some significance that the more asymmetrical the cornea, the larger the separation between the hyperbolas. Nevertheless, this does not fully explain the shape of the isogyres, though it would result in elliptical rather than circular isochromatics, as is indeed seen in these corneas. Some degree of lamellar orientation such as postulated by Schiötz may thus occur, though it should be remembered that the actual lamellae need not run along the principal vibration directions, but need only be

arranged in such a manner that these directions are the resultant of their individual effects. It is equally possible, moreover, that a change from a uniaxial to a biaxial type of interference figure is due not so much to the way in which the lamellae are arranged as to the effects of stress on the birefringence. As has previously been shown (Stanworth, 1949), tension on a strip of cornea results in a marked increase in the birefringence of the lamellae, and if this occurs more in some lamellae than in others, it may then alter the shape of the interference figure to that of a biaxial type. In this case the lines shown in Fig. 8 may give the directions of the principal stresses at any point, and would be described in photoelastic analysis as " isostatics ". If the distance between the points H and I is small these lines approximate to those in Fig. 7, indicating an almost radial and circular distribution of the stresses. That the stresses on the cornea may be responsible for the shape of the isogyres is indicated by the fact that the figure tends to become biaxial if the method of suspension is not physiological, if the cornea is dried, if it is fixed in formalin, or if it is markedly asymmetrical.

It is also possible that the lamellar arrangement and the influence of stresses may both be involved in producing the figure, for during the development of the cornea the lamellae may grow into their final positions along the lines of stress produced in the formative cornea by the rising intra-ocular pressure. Such an influence of stresses on growth has been postulated in the case of nerve fibres by Weiss (1934).

Summary

1. An apparatus is described for investigating the isolated cornea under near-physiological conditions in polarized light.

2. The effective birefringence for light passing normally through the cornea is extremely small, but increases rapidly with increasing obliquity of the light.

3. The " interference figure " seen between a polarizer and a crossed analyser is discussed in terms of photoelastic stress analysis and crystal optics, and is shown to be due primarily to the effect of the oblique incidence of the ray of light falling on the anisotropic corneal lamellae. Stresses in the cornea and the arrangement of the corneal lamellae may be secondary factors.

4. It is shown that though the interference figure is unchanged by a rise in pressure behind the cornea, this does not exclude a change in the birefringence of the individual corneal elements. This can only be studied by light passing obliquely through the

cornea so as to approach an isolation of the birefringence of lamellae running in one direction only.

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TREATMENT OF CONVERGENT SQUINT ASSOCIATED WITH HYPERMETROPIA*

BY

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From the Orthoptic Department, Nottingham and Midland Eye Infirmary.

FOR many years we have made, under the surgeons with whom we have worked, a study of the most beneficial glasses that can be ordered in conjunction with orthoptic treatment, because we have felt that the success of orthoptic treatment depends upon the glasses ordered, and we are convinced that glasses are the basis of orthoptic treatment.

In cases of convergent squint associated with hypermetropia, experience has shown us that, when the relationship between convergence and accommodation breaks down, the patient makes an excessive convergence effort to obtain clear vision uniocularly and, if diplopia has been present, to separate the images far enough for them not to be confusing. The suppression of the second image is thus facilitated. The breakdown between accommodation and convergence is primarily caused by accommodation exerted disproportionately to convergence in order to overcome the hypermetropia, and this breakdown is probably due to a deficiency in the power of relative accommodation, namely, the ability to accommodate in excess of convergence.

Most children are hypermetropic; it is not known exactly why this refractive state should induce squint in a minority of cases, but it may well be that deficiency in the power of relative accommodation is the decisive factor in producing deviation.

Ability to maintain clear binocular single vision at any distance is the hallmark of a normal pair of eyes, and as this function is mainly accommodational, the defect in accommodation must first engage our attention in cases of squint. We are convinced that, by readjusting accommodation, we are laying the foundation of a cure. Otherwise there is bound to be a weakness in the relationship between the two eyes. The ciliary muscle is therefore like a sick person who has to be nursed back to health and normal activity, gradually and without undue strain.

In order to rest and relax the ciliary muscle it is necessary to correct manifest and latent hypermetropia. Only when the need for accommodation is thus reduced, can the excessive convergence effort undergo relaxation.

To ascertain the necessary correction to do this, we have found that patients should have their accommodation completely paralysed by a cycloplegic (such as atropine), so that retinoscopy may

* Received for publication December 14, 1949.

reveal all the latent hypermetropia. Suppose retinoscopy is carried out at one metre distance, then full correction implies that the child should be ordered the shadow-turning lens less one dioptre, and without further subtraction for the cycloplegic used. Any astigmatism present should also be fully corrected. Many people claim that no child will tolerate such a full correction, but in our experience we have not found this to be so. The child should be corrected as soon after the onset of squint as possible. When a child has been under-corrected for a few years, it may be necessary, in a few cases, to maintain atropinization for about a week when the glasses are first worn. He will then wear them without any difficulty.

We realize that this correction is not generally used in all orthoptic clinics, and our object in writing this paper is to show why we think it is an integral part of the treatment. We believe that a full correction is necessary in order to overcome the excessive convergence effort. Many children appear to be straight in glasses, but converge one eye on being asked to fix a distant or near object. Questioning frequently reveals the fact that, when their eyes are straight, these children tolerate slightly misty vision for distance or near, or for both, but can overcome this by accommodating and consequently converging. By adding extra plus-spheres we have been able to clear the child's vision while the eyes are kept straight, and this in turn has prevented the child from over-converging for distance or near work. The lens that does this is the full correction by previous definition—that is, the lens that corrects the total hypermetropia. One of the most difficult cases with which an orthoptist has to deal is that of the child who is straight and orthophoric for distance, but over-converges one eye for near work. Orthoptists will find that the above method of correction will eliminate the majority of these cases.

Quoting from Lyle and Jackson (1949), it seems that what we would term a " full correction " they would term an " over-correction ". They say " . . . it is important to test the binocular visual acuity. This of course only appertains in those cases in which the visual axes are parallel for distant vision. It may be found that a better binocular visual acuity is obtained, in cases of hypermetropia especially, by the further addition of plus-spheres in front of each eye, in which case such additional plus spherical correction should be prescribed". We are confident that this correction should be prescribed in all cases of convergent squint.

We have found in our work that a child whose accommodation has not been entirely relaxed by the glasses tends to develop a small convergent angle of squint. This remains, and the squint becomes of the tonic type with an accommodative element. By

tonic we mean that natural adaptation of the muscles which has resulted from the active contraction of one muscle and the reciprocal relaxation of its antagonist. This excessive convergence effort results in suppression, which is greatly reduced immediately the need for the convergent effort is removed by a full correction. This is a tremendous factor towards gaining a satisfactory cure, as suppression plays such a large part in orthoptic treatment.

Apart from reducing the suppression, it will be found that this correction will straighten a large percentage of squints, and it should also be prescribed in the unilateral and alternating types of squints where operation is necessary. It is equally important to relax excessive convergence effort as suppression is reduced and muscle-tone is improved in these cases, and there is more chance of developing binocular single vision after the operation has been performed.

We are convinced that removing this excessive convergence effort is the first step in curing a squint. This seems to be substantiated by the fact that amongst the unilateral and alternating types of squints there are pre-operative cases who have barely simultaneous perception and do not respond to treatment. When first tested on the synoptophore ten days or so after operation, a number of these cases show definite signs of binocular vision which is rapidly improved with treatment, so that they become perfect cures. We know that if the eyes are put straight by operation there is a chance of binocular single vision developing, but we feel that this is not only because the eyes are straight but also because the excessive convergence effort has been relaxed. This has been further proved by the fact that, though the eyes may be put straight by operation, yet, because a small convergent effort is still present owing to the glasses being too weak, there is a tendency for the eyes to diverge or converge rather than to settle down around zero and develop fusion. Such cases show intense central suppression. This may be illustrated by the following case*:

Case 1. T. W. (aged 10½ years).

Defect.—Original R.C.S. Straight post-operatively.

Age of onset.—2 years.

History.—Gradual onset, attended clinic.

Partly dilated, R. and L. $-\overset{+4\cdot5}{|}+4\cdot5$

Ordered R. and L. +2·0 D. sph.

(*Aged* 8½ *years.*) Advancement Right External Rectus, with Recession Right Internal Rectus.

(*Aged* 9½ *years.*) Refracted R. $-\overset{+6\cdot25}{|}+6\cdot25$ L. $-\overset{+6\cdot25}{|}6\cdot75$

Ordered R. +4·5 D. sph. L. $\frac{+4\cdot5 \text{ D. sph.}}{+0\cdot5 \text{ D. cyl. } 90°}$

* Retinoscopies given in all examples are the shadow-turning lenses.

1st Test. (Aged 10½ years.) R.V. $\bar{c}$ gls. = 6/12. L.V. $\bar{c}$ gls. = 6/6.
Synoptophore.—Angle $\bar{c}$ gls. = 0°/−6°. Angle $\bar{s}$ gls. = +12°.
S.M.P.—Very unsteady, showing marked right suppression. Right image always moving.
Fusion.—No.

Off the instrument the child appeared straight during conversation, but he diverged the right eye when looking in the distance, and had no power of convergence. *His pupils were enlarged and showed no sign of contraction except to a light.*

In spite of working hard he showed no response to treatment. In order to prevent the divergence and to encourage the power of convergence his glasses were reduced, but in these he then converged during conversation. It was impossible to find a lens in which he did not either diverge or converge, and the treatment did not remove the intense central suppression or steady the right image.

It seems from this and similar cases that the accommodational defect must be corrected both by glasses and treatment before operation. Otherwise great difficulty is experienced by the patient in adjusting his eyes to obtain binocular single vision.

Chavasse (1937) says: "The probability that the normal developmental changes in the refraction of the eyes are influenced by adaptive use or disuse should be borne in mind in prescribing glasses for any growing child. The factors which secure that infantile ametropia normally issues in adult emmetropia are not yet defined. But the possibility that the wearing in childhood of a 'correction' for a normal degree of ametropia may influence adversely the attainment of adult emmetropia is ever present.

"The strength of the glass ordered should therefore be the weakest which keeps the squint in the occasional category. As soon as, in glasses, the squint is never present, the strength of the glasses must be further reduced. Otherwise the development of the harmonic accommodation reflex is obstructed, so that, when growth is complete, the glasses cannot be removed without precipitating the squint".

We do not feel that we can agree with this statement, because we have worked for many years with cases that have been "fully corrected" and we have never found any ill-effects developing then or in later years: on the contrary, these cases have responded better to orthoptic treatment. The correct relationship between accommodation and convergence has been more quickly established, and when the child has been "discharged as cured" following the treatment, his glasses are then, and only then, periodically reduced.

In children who are "under-corrected" as we would term it, we have found marked disturbance of accommodation. It would seem that these children suffer from fatigue of accommodation resulting from the continual necessity to see clearly, and the power

of accommodation becomes faulty in consequence. This fatigue manifests itself in (1) enlarged pupils which contract to a light and do not do so to accommodation, and (2) lack of proper convergence. The child is able to read at a normal distance, but he is conscious of seeing better at a slightly greater distance. These cases rarely become a satisfactory cure because their fusion is faulty, and their adduction almost nil, and there is little real relationship between the two eyes.

To illustrate the importance of the functioning of accommodation we quote the following example:

Case 2. S. B. (aged 7¾ years).
Defect.—Original R.C.S. Straight post-operatively.
Age of onset.—4½ years.
History.—Gradual onset, attended clinic.

Refracted R. $-\frac{+5{\cdot}25}{+5\ 25}$ L. $-\frac{+4{\cdot}75}{+4{\cdot}75}$

Ordered R. +2·5 D. sph. L. +2·0 D. sph.

(*Aged 7¾ years.*) Advancement Right External Rectus with Recession Right Internal Rectus. Immediately after operation referred for treatment.

1st Test.—While in-patient.

Synoptophore.—Angle $\bar{c}$ gls. = +5°. Rt. $\backslash^{\text{Lt.}}$ 2A.

S.M.P.—Spasmodic, but never held, pictures "shoot across" most of the time.

Fusion.—No.

Off the instrument this child was quite straight with no cover test, but he had enlarged pupils and no power of convergence. We treated him on the synoptophore in the usual manner, but without response. We were unable to steady the S.M.P. or to develop fusion. We then started an attack on the pupils by working with plus- and minus-lenses on and off the synoptophore, making him look into the distance and converge to a near finger, and indeed anything that would alter the size of the pupils. At first we met with no response. The child had no convergence to a finger, and in order to "clear", even a −1·0 D. sph. in front of each eye, he pushed one eye "in" instead of accommodating. During the second treatment of this kind we noticed improvement. There was a slight contraction of the pupils and a better attempt at convergence. The third treatment showed further improvement, and when he was tested on the synoptophore he showed definite signs of fusion, and was altogether steadier. This has improved, and the child is now responding well to treatment.

These cases with fatigue of accommodation are difficult to improve, but we have found the above method very satisfactory. We are able thus to cure some of these cases, which would formerly have been discharged as "cosmetic" cures.

The following practical points illustrate our argument in favour of full correction:

(1) The need for excessive accommodation is removed, and the facility with which the child over-converges is curtailed.
(2) Suppression is greatly reduced.
(3) The angle of squint is removed unless there is any tonic element, and the case can be cured by treatment alone.
(4) Full correction greatly minimizes the chance of an abnormal retinal correspondence developing.

Orthoptists know that there are certain conditions that are unresponsive to orthoptic treatment, but we believe that a full correction from an early age is particularly beneficial in the following types:

(1) Variable angles of squint.
(2) Cases of over-convergence when fixing a distant object.
(3) Cases of over-convergence when fixing a near object.
(4) Small convergent angles with no binocular vision who attempt a false associated fixation at zero.
(5) Cases of intense central suppression which do not yield to treatment. These, at the best, will only be a semi-orthoptic cure if any fusion can be obtained.
(6) Cases having simultaneous perception but unable to develop fusion owing to the continual slight slipping "off" of one eye. Inexperienced orthoptists might work on and develop a slightly false fixation in these cases.
(7) Enlarged pupils which do not contract during an effort to accommodate or converge, associated with absence of normal adduction and convergence.

From the age of onset our aim is, if possible, to maintain binocular single vision with the aid of glasses until the child is old enough for treatment. We find that a full correction is the best way of doing this, because there is more chance of the eyes being kept straight all the time, and less chance of suppression developing.

It has been interesting to note that children on regular treatment who have been, as we would term it, under-corrected, show a constant or occasional angle of squint with marked suppression. Sometimes these children have barely simultaneous perception, but, as extra plus-lenses are added on the synoptophore, this suppression is immediately reduced and simultaneous macular perception obtained. If the extra correction can be given soon after the onset of squint, the small convergent angle or variable angle will be overcome. If the small angle of convergence is allowed to remain, and if it becomes consistent, abnormal retinal correspondence with marked suppression around the true angle is likely to ensue. We believe that these are the cases of abnormal retinal correspondence which orthoptists claim to overcome in a few treatments. In such patients operation may immediately secure binocular single vision. In reality these are cases of under-corrected accommodative squint with a desire for fusion. Most of them, if a full correction had been prescribed, would never have developed a small convergent angle at all, but would have maintained weak binocular single vision which could have been perfected by treatment at a later stage.

Some of our observed cases of squint with a small static convergent angle in glasses have become quite straight when the glasses were removed, and they even tolerated misty vision. As soon as the glasses were put on again, the static convergent angle reappeared, because the child had found that, by maintaining a

small amount of convergence, he could see quite clearly in his glasses. By this effort of convergence he was overcoming the residual uncorrected hypermetropia. By giving him this extra correction we remove the static angle, and he can see clearly in his glasses with his eyes straight. We do not want this type of squint to be confused with the accommodative type which converges on fixing a distant or near object.

The following cases illustrate, from the orthoptic point of view, the advantages of a full correction.

Case 3. M. S. (aged 6½ years).

Defect.—R.C.S. variable, converging more on fixing.
Age of onset.—5 years.
History.—Gradual onset, attended clinic.

+5·5.
Refracted. R. and L. —|—+5·5

Ordered R. and L. +3·0 D. sph. Referred for pre-operative treatment.

1st Test (aged 6½ years).—R.V. $\bar{c}$ gls.=6/12 pt. L.V. $\bar{c}$ gls.=6/12.
Synoptophore.—Angle $\bar{c}$ gls.=+20° variable. Angle $\bar{s}$ gls.=+40° variable.
S.M.P.—Yes, variable, with marked right suppression.
Fusion.—Seemed to be present, but was variable and unsteady, and showed marked right suppression.

Quoting from report, "On the instrument the angle is much reduced by adding a +2·0 D. sph. each eye, and child can join fusion pictures at +5°, holding both control marks, whereas with her own glasses she joins the pictures at +15°/18° and loses the right control, showing how much the suppression is increased by accommodation".

This child was then ordered R. and L. +4·5 D. sph., in which she was quite straight with all the grades of binocular vision, and she was discharged as an orthoptic cure without operation after 16 treatments.

Case 4. M. C. (aged 8 years).

Defect.—L.C.S. can alternate.
Age of onset.—10 months.
History.—Measles. Attended clinic immediately.

+7·0 +8·5
(*Aged 2½ years.*) Refracted R. —|—+7·0 L. —|—+8·5

Ordered R. +4·5 D. sph. L. +6·0 D. sph.

1st Test (aged 8 years).—R.V. $\bar{c}$+4·5 D. sph.=6/5. L.V. $\bar{c}$+6 D. sph=6/5.
Synoptophore.—Angle $\bar{c}$ gls.=+20° very variable. No simultaneous perception.
S.M.P.—No.
Fusion.—No.

After three treatments child only obtained spasmodic simultaneous perception. She was refracted again and was ordered a full correction, namely R.+5·5 D. sph. L.+7·0 D. sph. With this correction the suppression was greatly reduced and she had comparatively steady S.M.P. at about +5°. After five treatments she could join large fusion pictures, steadily holding both controls all the time, but with one dioptre less in each eye, the fusion hold became weak, and the right control kept coming and going. She gradually became quite straight, and capable of fusion, ductions and stereoscopic vision, but she is still under observation, as at times she has misty vision for near work when maintaining binocular single vision, owing to fatigue of accommodation; but this is improving. The pupils, which were very enlarged, are becoming normal.

Case 5. J. H. (aged 7 years).

Defect—L.C.S. Appearance $+15°$ $\bar{c}$ glasses.
" $+25°$ $\bar{s}$ glasses.

Age of onset.—3 years.

History—Occasional squint, gradual onset, attended clinic immediately.

Refracted R. $-\left|-\right.^{+4\cdot0}_{+5\cdot0}$. L. $-\left|-\right.^{+4\cdot0}_{+5\cdot5}$. No glasses ordered.

(*Aged* $4\frac{1}{2}$ *years.*) Constant L.C.S.

Refracted R. and L. $-\left|-\right.^{+5\cdot5}_{+5\cdot0}$

Ordered R. and L. $+2\cdot5$ D. sph.

(*Aged* 7 *years.*)

Refracted R. and L. $-\left|-\right.^{+5\cdot5}_{+5\cdot5}$.

Ordered R. and L. $+3\cdot0$ D. sph.

1st Test (aged 7 years).—R.V. $\bar{c}$ gls.$=6/6$. L.V. $\bar{c}$ gls.$=6/9$ pt.
Synoptophore.—Angle $\bar{c}$ gls.$=+18°$. Angle $\bar{s}$ gls.$=+25°$.
S.M.P.—Yes, with marked left suppression.
Fusion.—No.

Little response to treatment was shown. Her correction was increased to a full correction, *i.e.*, R. $\bar{c}+4\cdot5$ D. sph.$=6/5$ pt., L. $\bar{c}+4\cdot5$ D. sph.$=6/6$ pt., but it was too late after onset to be effective, and the angle of squint remained. Suppression had become too intense as a result of the excessive convergence effort to respond to treatment.

Although she has the history of a typical accommodative squint, she had to have an operation to remove the angle, and after further treatment—34 attendances in all—she was discharged as cosmetically straight.

It seems that if this child had been fully corrected from the age of onset she would probably have been a typical accommodative squint curable by treatment alone. She also had enlarged pupils.

We should like to comment here on what have been termed emmetropic accommodative squints, because we have never found a case that would fit into this category. From the practical point of view of trying to cure the squint, we have always found that, by temporarily correcting the latent hypermetropia however small, glasses have eliminated over-convergence, and the case has become a typical accommodative, able to discontinue glasses within a reasonable time after a cure has been effected.

Case 6. C. F. (aged $8\frac{1}{2}$ years).

Defect.—Occasional R.C.S.
Age of onset.—$4\frac{1}{2}$ years.
History.—No glasses worn; received orthoptic treatment elsewhere. Referred to us for continuance of treatment. Report stated child sometimes saw mistily when eyes were straight.
1st Test (aged $8\frac{1}{2}$ years).—R.E.$=6/9$ pt. L.E.$=6/6$ pt.
Synoptophore.—Angle $=+5°/8°$.
S.M.P.—Yes, with right suppression.
Fusion.—Yes. Adduction weak, shows right suppression.
Stereoscopic vision.—Weak.

This child was refracted and was found to be R. and L. $-\left|-\right.^{+2\cdot5}_{+2\cdot5}$. She was ordered R. and L. $+1\cdot0$ D. sph. With these the squint was less apparent and she was perfectly comfortable in them.

Synoptophore (after 8 treatments).—Angle $\bar{c}$ gls. = +4°/5°. Angle $\bar{c}$ out gls. = +4°/5°. No suppression apparent.
S.M.P.—Yes.
Fusion.—Yes. Adduction.—20°. Abduction.—3°.
Stereoscopic vision.—Yes.
Physiological diplopia.—Yes.

She has maintained improvement, but when she started treatment she had a marked fatigue of accommodation. When this has fully recovered she will be able to discontinue glasses.

In our method of giving treatment closely allied with the treatment of the accommodational element, we believe that it is equally important to train the adduction immediately fusion develops. Accommodation and convergence are associated functions; it is therefore reasonable to suppose that one helps the other, and a normal relationship is thus more quickly established. We have found that by concentrating on the adduction training and ignoring abduction, fusion has become " strong " more rapidly, suppression is eliminated, and stereoscopic vision developed. Unless carefully watched, abduction training can pull eyes out on to a slightly false fixation, but this danger is avoided if the fusion has first been strengthened by adduction exercises.

It appears that this method of treatment is not universal. Many people fear that it might increase the angle of convergence, but we do not find this to be so. We use it in all cases of squint with fusion, both pre-operative and post-operative. Once good adduction on the instrument and normal convergence off the instrument have been obtained, there is little fear of a relapse.

Some years ago we studied the correction of refractive errors in cases of squint, particularly in young children soon after onset. We recorded a consecutive series of young children attending the Out-Patient Department for the first time shortly after the squint was noticed. All these children were refracted under atropine, given a full correction, and told to report after wearing the new glasses for a month. Of 124 children who returned, it was interesting to find that 89 were straight in their glasses, and the remaining 35 still showed some deviation. The fact that 72 per cent. were straightened by glasses proved our methods of treatment were worthy of further investigation. Our subsequent experience in treating some of the above cases, when they were old enough, and others similarly corrected, has left us in no doubt that successful orthoptic treatment of concomitant squint depends largely upon the full refractive correction being ordered as soon as the deviation becomes manifest.

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AQUEOUS VEINS IN GLAUCOMATOUS EYES*

BY

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ONE of us has previously found (Thomassen, 1947b) that the aqueous veins in eyes suffering from simple glaucoma convey little or no clear liquid when the bulbar tension is in an increasing phase, whereas the clear outflow through them is augmented when the bulbar tension is in a decreasing phase. The main intention of this paper is to extend this observation by means of photographs. Gärtner (1944) and de Vries (1947) have already successfully photographed aqueous veins. Those accompanying this paper were taken by the Medical Illustration Department of the Institute of Ophthalmology.

Method

The bulbar tension was measured half hourly with a Schiötz X-tonometer. Before each measurement the eyes were anæsthetized with one drop 1 per cent. pantocain solution. By means of the repeated measurements it was possible to estimate whether the bulbar tension was increasing or decreasing. For further details concerning the estimation of the phases in the tension, the reader is referred to earlier explanations (Thomassen, 1947a; Thomassen and Leydhecker, 1950). It is obvious that the repeated tonometry and the drops irritate the eye and therefore produce a generalized hyperæmia of the conjunctival vessels and aqueous veins. Observations and photographs have therefore been taken immediately before each new measurement, thus allowing time for the irritation from the previous measurements to subside.

In some cases the observation has been made difficult by another phenomenon. It has been found that the light from the slit-lamp can increase the amount of blood in the aqueous veins. In one case such a change was particularly striking. The patient, who had a simple glaucoma in both eyes, was observed on eight different days. In the left eye a large aqueous vein was seen with almost clear contents. When the light was switched on the speed of the current slowed down and after a short time the contents were rocking to and fro synchronously with the heart-beat. At the same time the vein was filling with blood. Finally, the contents of the vein, now only blood, were running quite freely in the direction opposite to that previously observed. After a short time in the dark the clear fluid was running as before, but

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when the light was put on the same changes always took place. Sometimes the changes appeared after a few seconds, but sometimes a longer period of illumination, up to one minute or more, was necessary. The bulbar tension was not found to play any definite part in the phenomenon. Changes as dramatic as this have been observed only in this single case, but in some other cases a slightly increased amount of blood in the aqueous veins has been seen when the eyes have been exposed to bright light. These observations do not substantiate the findings in normal eyes of Ascher (1942*b*), that light increases the flow of clear liquid. It may be, however, that the phenomenon seen in our case is caused by the heat of the slit-lamp beam and not by the light itself.

Results

More than thirty patients with glaucoma have been examined, but most of the observations have been more or less equivocal. Only one case will therefore be described in detail. In this case the changes were very marked and we had the opportunity of making repeated observations so that the phenomena observed must be considered established.

This one patient, a woman 60 years old, had suffered from attacks of misty vision and haloes round lights for three years. The anterior chambers were rather shallow and the fields showed some peripheral contraction. She had never had an acute attack but nevertheless the disease could not be regarded as a simple glaucoma. She had used pilocarpine for one year, but no operation had been performed on her eyes. On the nasal side of the right eye was seen a large aqueous vein whioh originated near the limbus from several small tributaries. Fig. 1 shows the changes in tension in this eye from 10 a.m. to 4 p.m. on September 14, 1949 (no pilocarpine having been used for 36 hours). To begin with, the tension was in a decreasing phase and the contents of the aqueous vein appeared almost clear (Fig. 2). It should be noted that one drop of pantocain solution had been instilled into the eye and the bulbar tension measured once before this photograph was taken. Some minutes after the measurement at 10.30 a.m. it was observed that the vein was filled with blood, and from the curve it can be seen that the bulbar tension started rising. This appearance of the aqueous vein (Fig. 3) remained constant while the bulbar tension was in the increasing phase. It was remarkable that even the small tributaries were filled with blood and that the current had the same direction and about the same speed as before. The blood must therefore have displaced the aqueous intrasclerally, perhaps in Schlemm's canal. Unfortunately it was impossible to see this canal by gonioscopy on account of the shallowness of the anterior chamber. During the last 10 minutes before the measurement at 11.10 a.m. the vein became less engorged and the blood in the aqueous vein seemed to be a little diluted. After this measurement more clear liquid was again visible in the aqueous vein, particularly in the upper branches, and produced a marked stratification (Fig. 4). Unfortunately this photograph is not quite in focus, but a broad dilute stream in the upper part of the vein is visible. The pressure was now in a slightly decreasing phase and the aqueous vein appeared unchanged until, at about 2.00 p.m., it was again filled with blood and appeared the same as in Fig. 2. The bulbar tension was now again in an increasing phase. As it was necessary to conclude the investigation within a limited time pilocarpine was instilled into the eye and as a consequence the tension again dropped. During this decreasing phase Fig. 5 was taken. This shows a marked stratification due to the presence of an increased amount of clear liquid in the upper part of the vein.

The objection may still be advanced that the pantocain and tonometry influence the results, in spite of the fact that the clear fluid in this case reappeared spontaneously after 4 drops of pantocaine and as many measurements of the tension. This patient has been examined altogether 12 times in the course of 3 months. Each time no pilocarpine has been used during the previous 36 hours. The significant observation was made that the aqueous vein contained mainly clear liquid every morning. Between 10 and 11 a.m. the vein became filled with blood in the

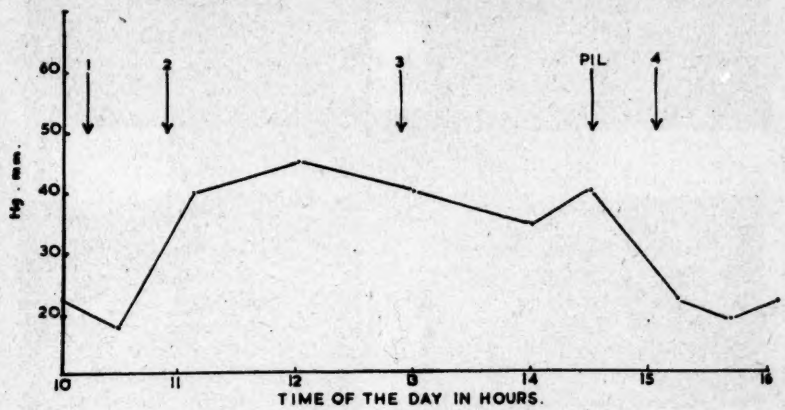

FIG. 1.—The oscillation of tension in a glaucomatous eye during one day. Pil. means that a 2 per cent. solution of pilocarpine is instilled into the eye. Arrows 1 to 4 refer to the moments when Figs 2 to 5 were taken.

course of 10-15 seconds. This alteration took place even if nothing were done to the eye except observation with the slit-lamp. Figs 6 and 7 were taken on such a day when no measurements had been made. Fig. 6 shows the same appearance as Fig. 2 and Fig. 7 is similar to Fig. 3. In Fig. 3 the aqueous vein in question is seen to be somewhat broader than in Fig. 6. This may be caused by the drops and tonometry done before Fig. 3 was taken. In fact, when nothing was done to the eye, no hyperæmia was seen in the increasing phase except the filling of the aqueous veins with blood and some dilatation of small veins joining it. Figs 8, 9, and 10 were taken by one of us (E. S. P.) on another day when no measurements of tension were performed. Fig. 8 was taken in the same phase as Fig. 2, Fig. 9 in the increasing phase (corresponding to Fig. 3), and Fig. 10 after the instillation of pilocarpine as in Fig. 5. The changes in this particular aqueous vein were indeed so regular that after a few days' observation we were able to tell by its appearance whether the bulbar tension was

in an increasing or decreasing phase, and tonometry proved that we were never wrong. Only twice did the bulbar tension decrease again spontaneously after the pronounced increase. On other days the tension increased so much that pilocarpine had to be instilled.

FIG. 2.

FIG. 3.

FIG. 4.

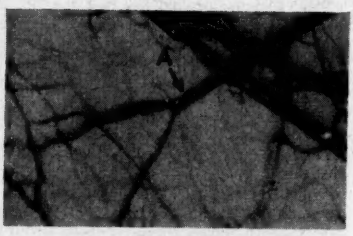

FIG. 5.

FIG. 6.

FIG. 7.

Figs 2–5 show the different appearances of the aqueous vein "A". Figs 6 and 7, taken on another day when no measurements of the tension were made, show the same aqueous vein "A".

The observations on this case show that at least in some glaucomatous eyes there must be a close relationship between the appearance of the aqueous veins and the changes in the bulbar tension. There are three possible explanations of this relationship :

FIG. 8.

FIG. 9.

FIG. 10.

Figs 8, 9, and 10 showing the same aqueous vein "A" were taken some weeks later than 2-7, again without any measurements being made. Fig. 10 shows the vein "A" after the instillation of pilocarpine.

(1) Thomassen (1947a) has emphasized that the venous pressure in the globe is high when the bulbar tension is increasing and low when it is decreasing. When the venous pressure is high it is easy to understand that the aqueous will

be displaced by blood. The outflow of aqueous humour will therefore also be hampered, causing the bulbar tension to increase.

(2) Ascher and Spurgeon (1949) and Goldmann (1948) have emphasized that the pressure in the aqueous veins is decreased in glaucomatous eyes. This can of course explain our findings if it is supposed to occur only during the increasing phase.

(3) The third possible explanation is that there is no causative relation between the phenomena. That is to say that the increase of blood in the aqueous veins is a vascular phenomenon similar to the hyperæmia caused by irritation.

The pressure in some of the episcleral veins was measured by means of the water manometer described by Thomassen (1947a). In the first decreasing phase it was found to be about 5 mm. Hg in the aqueous vein as well as in most of the other veins. When the bulbar tension started increasing the pressure in the aqueous vein and in the small veins connected with the aqueous vein also increased and rose by degrees to 14 mm. Hg. The rise in the venous pressure was not found to precede the rise in bulbar tension. Most of the other veins did not show any change in pressure. In some deep veins, however, marked changes were found, but again they did not precede the changes in the ocular tension. In any case the rapid change in the bulbar tension makes it very difficult to be sure that changes in the venous pressure precede the changes in ocular tension.

In conclusion, some observations on other glaucomatous eyes should be briefly mentioned. In some cases when the patient was first seen while the bulbar tension was in an increasing phase no aqueous vein could be found, although subsequent examination in the decreasing phase showed them to be present. In one case a marked narrowing of the blood column was seen during the increasing phase where the smaller veins entered the side of a larger vein. When the tension decreased again this could no longer be observed.

Gartner (1944) has shown that pilocarpine increases the outflow of clear liquid through the aqueous veins. Ascher (1942) has described the same phenomenon, but he finds it does not occur in every case. We can confirm their findings in so far as pilocarpine can increase the outflow, but only when it produces a decreasing phase in the bulbar tension. If pilocarpine does not produce this decrease in tension only a hyperæmia in the episcleral veins is seen and there is no alteration in the aqueous veins.

Summary

The authors confirm by means of photographs the phenomenon previously described, that at least in some glaucomatous eyes the aqueous veins tend to be filled with blood when the bulbar tension is in an increasing phase and convey more clear liquid when the bulbar tension is decreasing.

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PREPARATION OF OPHTHALMIC SOLUTIONS: MODERN CONCEPTS.

I.—Atropine Sulphate *

BY

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FOR a long time there were no general rules regarding isotonia and isohydria of ophthalmic solutions and lotions, or rather no attention was given to this subject when prescribing or preparing drugs.

The pH of human tears varies between 7 and 8, the average being 7·3. This was also found by Swan. Other findings were:

Charlton	7·2	Pelláthy	7·6-8·0
Györffy, Verzella	7·2-7·5	Kusunocki	7·4-8·4
Dekking	7·6	Blok	7·8-8·0
Obrig	7·3-7·7	Roulet, Gifford	8·0
Gardilčić	7·5-7·9	Oguchi, Pedersen B.	8·5

It may be that higher values are due to lacrimation produced by the irritating effect of glass-electrodes. According to these authors pure tears are more alkaline than the conjunctival fluid (a mixture). The triple structure of the precorneal film was emphasized recently (Wolff).

Even in the latest pharmaceutical text-books there are but few directions regarding the preparation of ophthalmic solutions, and only in respect to isotonia. Thus for instance the V. Swiss Pharmacopoeia (1933) prescribes quite generally the use of distilled water and recommends addition of boric acid if the drops are turbid. According to the XI. Swedish Pharmacopoeia (1946) and the IX. Danish Pharmacopoeia all lotions are prepared with distilled water and made isotonic by adding sodium chloride (except silver nitrate). Another prescription demands that the solution be isotonic with tears (freezing point—0·8); schedules usually give the necessary directions.

Recently numerous investigators have taken up the question of isotonia. The older assumption that a 1·4 per cent. Na Cl solution is isotonic with lacrimal fluid is not substantiated (Krogh, 1945); the freezing point of tears is 0·56. (Dale and Husa, 1948; Pedersen-Bjergaard, 1948.) The osmotic pressure of tears is equal to that of physiological saline. Accurate adjustment is not imperative, as the eye tolerates a wide range of osmotic values (0·5-2·0 per cent. Na Cl; Hind and Goyan, 1947).

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Results obtained by various authors regarding the pH of eye drops were by no means uniform. While some recommended the value 6·75 as optimal for eye solutions, others ascertained long ago that it is neither necessary nor possible to prepare these drugs with exactly the same pH. Some consideration was given to the side effects, due to presence of active bases, irritating to eye tissues.

An up-to-date description of preparing isohydric lotions is to be found in the Commentary of the Swiss Pharmacopoeia. The pioneer work of Gifford (1935) influenced one of us in recommending alkaloids to be dispensed in the alkaline region; this must be reconsidered. Lower values were given by Skolaut (1948) 6·8-6·0; Blok (1945) reports that a half per cent. atropine solution underwent a 44 per cent. decomposition at pH 8·3, while homatropine showed a decomposition of 89 per cent. A very comprehensive study by Hind and Goyan (1947) emphasized the importance of the chemical stability of ophthalmic solutions. We refer to their excellent paper, where five groups are given in dispensing stabilized drugs. The found the concentration of free atropine base at pH8 2·2 per cent. and at pH9 18·3 per cent. The role of free base liberated by hydrolysis is stressed in evaluating activity and side effect. The reactions encountered in a solution of an alkaloid are as follows:—

$$\text{salt} \rightleftharpoons \text{active ion} + \text{chloride (or sulphate) ion}$$
$$\text{active ion} + H_2O \rightleftharpoons \text{base} + \text{hydrogen ion}$$

The concentration of free base at various pH levels may be calculated from the constant of the base (Table I of Hind and Goyan, 1947), expressed in mol per cent. of free base. As to the question of preventing mould growth, we recommended previously nipa-bodies (esters of p—hydroxybenzoate). Zephyran† seems to be very adequate; the value of sodium propionate, a new fungicide should be investigated. The problem of eserine will be discussed elsewhere.

Experimental Findings

As the views of the different authors regarding decomposition of alkaloids are often contradictory (*e.g.*, Hind as against Blok) it proved necessary to examine this question. The behaviour of atropine sulphate solution (1 per cent.) was studied. By using modified Palitsch (1915) boric acid-sodium borate buffers we prepared a series ranging from pH 5 to 9 as shown in Table I; zephyran was added in a concentration of 1 : 50,000.*

† Zephyran (benzalkonium chloride) is a cationic detergent of high self-sterilizing quality, used at the Wilmer Institute in a concentration of 1:5000.

TABLE I

pH	0·2 mol Boric Acid cc.	0·05 mol Borax cc.	Grams NaCl per 100 cc.
5	0·356 Mboric acid sol.	—	0·20
6	100	—	0·20
7·09	94	6	0·22
8·08	70	30	0·25
8·98	20	80	0·29

The physiological activity was studied by measuring the pupillary diameter with Wessely's keratometer before instillation and then, after 20, 40, and 60 minutes, at constant illumination. It is a well known fact that mydriasis sets in 10 minutes after instillation, attains its maximum degree 30 minutes later, and then decreases gradually. Blinking was avoided if possible, and colour of iris noted.

TABLE II

Mydriatic effect of 2 drops 1 per cent. atropine sulph. (mean values)

pH	No. of cases	Increase of pupillary diameter (mm.)	
		after 40 mins.	after 60 mins.
5	6	2·4	2·4
6	3	2·5	2·5
7	4	3·0	3·1
8	3	3·0	3·1
9 (fresh)	7	2·4	3·7
9 (2 months old)	3	2·6	3·0

The degree of mydriasis rises gradually in proportion with the increase of pH. Then we compared the behaviour of a fresh solution pH9 with one which was two months old.

The difference between the two drugs with regard to pharmacological activity is negligible.

Considering the irritating effect of more acid lotions we were surprised to see that such symptoms were absent. Not once did we observe hyperaemia, burning sensation, etc., after a single application of the drug. However, frequent instillation during the long course of an illness may possibly lead to intolerance. (It should be mentioned that lacrimation diminishes the lysozyme-content of tears : atropine—by reducing secretion—raises it again). It may be stated that the mydriatic effect is more or less the same, showing no irritative side-effects : the activity of a solution with higher pH is only very slightly intensified. This clinical statement is contrary to the experimental data of Cori, etc., who used cats and the isolated iris.

Concurrently we determined the change of atropine sulphate into base: we worked out the following method, led by the general characteristic of alkaloids, that alkaloidal salts dissolve in water, but not in chloroform and *vice versa*, bases dissolve in chloroform and not in water. So if chloroform is shaken with the test substance and the chloroform-solution is dehydrated, only the alkaloid in base form will dissolve. Our supposition proved to be right. We also studied the alkaloid-content according to the method of Schulek-Szeghö, with the difference that we did not add ammonia to the aqueous solution.

1 cc. of the solution was shaken together with 70 cc. of chloroform for several minutes: then anhydric sodium sulphate was added to the mixture, to give it a powder like aggregation non-adhesive character. We then poured the chloroform solution through filter paper containing a few grams of anhydric sod. sulphate and evaporated the chloroform. 10 cc. 0·02 N. sulphuric acid was added to the residue and retitrated with 0·02 N. NaOH, using methyl red indicator.

The solution was kept in transparent bottles in a dark place so that changes could be observed. As 3 to 4 weeks after dispensing the drug moulds appeared, we raised the concentration of zephyran to 1:20,000.

We estimated the concentration of free base directly after dispensing, then after 3, 14, and 25 days. We determined further the whole atropine content (salt); it was thought that atropine having an esteric character, would decompose in an alkaline milieu. For the sake of comparison the changes were observed in an unbuffered solution as well.

TABLE III

pH	Time of determination after preparation							
	Immediately		3 days		14 days		25 days	
	a	b	a	b	a	b	a	b
5	95·4	16·2	94·7	23·7	91·3	25·0	93·4	31·8
6	94·7	14·9	94·0	19·6	91·3	21·7	90·7	30·4
7	95·4	6·8	94·0	10·2	92·7	14·9	92·0	29·8
8	95·4	94·0	91·3	60·2	88·6	73·1	86·6	32·5
9	94·7	93·4	90·0	64·2	78·5	76·4	79·1	29·1
unbuffered	96·4	4·1	93·4	4·8	80·5	13·5	82·5	27·7

a = total atropine-content, expressed as atropine sulphate (percentage).
b = free base, expressed as percentage of a.

For the sake of comparison b is given as atropine sulphate also. The difference between a and b represents atropine in ionic state.

As the data prove, after preparation the atropine sulphate content of all the solutions was approximately the same (94·7-96·4 per cent.). The exactitude of determination can be said to amount to ± 1 per cent. The concentration of the free base after preparation was lowest in pH 7 solution, somewhat higher in the pH 5 and 6 types. The atropine was almost entirely in base form in solution of pH 8 and 9. During storage the base content slowly increased in pH 5-7 drugs, while in pH 8 and 9 it gradually diminished.

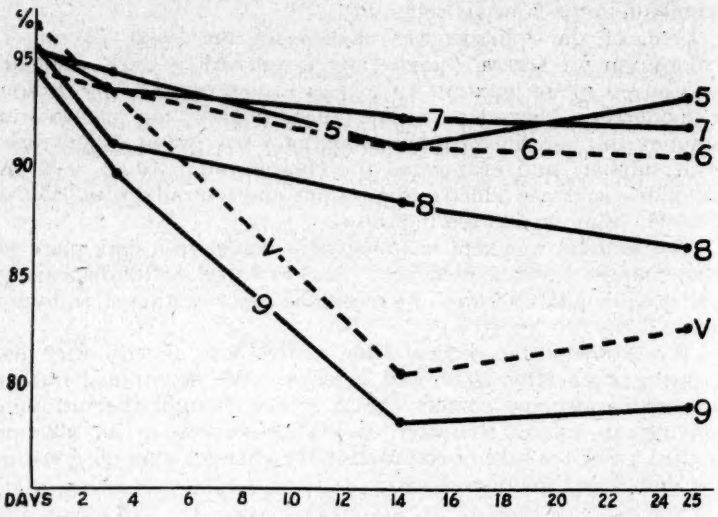

FIG. 1.—Total atropine content, expressed as percentage (ordinate), related to the time element in days (abscissa).
The lines indicate solutions of varying pH. v = unbuffered solution.

Finally after 25 days the base concentration of atropine showed values of about 30 per cent. irrespective of hydrogen ion concentration.

While being stored the total amount of salt diminishes: in type 5-7 this decrease is negligible, in pH 9 the dissociation is appreciable after 2 weeks. The change in simple aqueous solutions without buffers is also interesting: in spite of the fact that in the beginning the atropine-base value was low, the reduction was almost the same in 2 weeks as with pH 9 solution. During the last ten days the total amount of atropine sulphate scarcely underwent any change in the different types (Figs 1 and 2).

The published data should not be considered as absolute values; possibly atropine, developing during decomposition, dissolves.

The rate of decomposition, however, is borne out by complete uniformity of experimental circumstances.

Our results show clearly why the data of different authors vary so widely regarding decomposition of atropine, the *concentration of the free base being a function of time.* According to our findings the base concentration changes considerably, but the

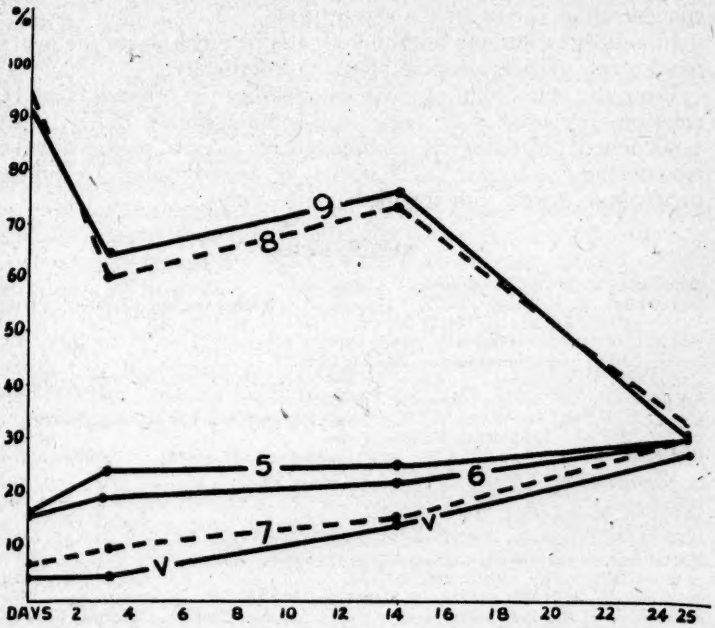

FIG. 2. Change of the free base concentration (percentage) as a function of time in days.
The lines indicate solutions of varying pH. v = unbuffered solution.

investigators quoted never mentioned how long after dispensing the solutions they carried out their tests. The decomposition of the atropine molecule in simple aqueous solution, as well as in pH 8 and 9 types is very remarkable. According to biological tests, with isotonic solutions the effect is in no close relation to the change of pH 5-9, or rather the increase of activity in relation to higher pH levels is not significant. Type pH 7 is recommended in order to obtain a stable solution, without sacrificing pharmacological activity.

Summary

Isotonic atropine sulphate solution — regardless of its pH — does not irritate the eye: simple aqueous solution (unbuffered) causes a burning sensation.

There is no distinct difference between the activity of atropine base and ion, not even when the solutions contained atropine entirely as bases or ion. The proportion of base and ion concentration varies after a certain time.

In aqueous solutions (unbuffered) and in types above the neutral point (*e.g.*, pH8-9) atropine splits hydrolytically.

From the standpoint of chemical stability the optimal is a pH 7 solution, prepared with boric acid-sodium borate buffer, which approached physiological circumstances. As a preservative we recommend zephyran (1 :20,000). It is advisable to prepare ophthalmic drugs with distilled sterile water.

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THE CURE OF CAVERNOUS SINUS THROMBOPHLEBITIS*

BY

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SUPPURATION in the adnexa of the eye is always serious, as we can never be sure that the seemingly harmless stye may not cause a retrobulbar phlegmon, and subsequently cavernous sinus thrombophlebitis may develop on account of the rich anastomoses between the two areas. Every ophthalmologist can remember more than one case in which it was impossible to save the patient's life.

Until recently, the different antibodies, *e.g.*, intravenous hexamethylenetetramine, trypaflavin, etc., have been of no avail, nor were the sulphonamides a success, so that we were absolutely helpless when faced with this condition. The discovery of penicillin, however, has solved the problem, as it seems that the disease can be cured, if penicillin in adequate concentration can reach the infected areas by way of the spinal fluid.

We know of so few cases reported in the literature that we feel justified in supposing that the therapy of this illness has not yet been standardized. I think it may be useful, therefore, to publish two cases which we were able to cure.

Case 1.

H. J., a boy, 3 years of age, was brought to our department on August 12, 1947. The patient's mother said that the child had had measles a fortnight before; two small papules remained on his right lower lid. On the morning of the day before the child was brought to the hospital, his right upper lid began to swell. In the evening this swelling became worse and the patient developed a high temperature.

When the child was admitted to hospital both lids of his right eye were red and very swollen and the protrusion was 1-1·5 cm. The boy was somnolent and had a temperature of 104° F. On the left side a moderate oedema of the lids was visible, the other parts of the eye were normal. The back of the neck was slightly stiff, the spinal fluid faintly cloudy, the number of cells was 100-120. The diagnosis was *retrobulbar phlegmon of the right side, incipient cavernous sinus thrombophlebitis.*

The treatment consisted of a moist dressing, 4 tablets of sulfa-methylthyasol daily, and the intramuscular administration of 20,000 units of penicillin every three hours.

On the following morning the patient's temperature had dropped to 98·5° F., the oedema of the left eye-lid was almost completely gone and the child was much more lively. The blood picture only showed an increase in the leucocyte count (12,000). The rhinological examination revealed a very small amount of purulent secretion on the posterior end of the middle concha, so we resolved to continue the penicillin treatment and to remove the ethmoidal cells. This offered no difficulty.

Until August 17 we carried on the systematic penicillin treatment and up to that day (the 5th) the patient had been given 1,200,000 units intramuscularly. His

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temperature became normal and the exophthalmos of the right eye began to recede. Then the penicillin treatment was stopped.

On August 18 the patient became feverish and his temperature rose to 104° F., the exophthalmos became worse and he grew extremely restless. We gave him 20,000 units of penicillin every three hours intramuscularly and a blood transfusion of 100 cc. daily.

On August 20 the patient's condition improved, his temperature was normal; the exophthalmos receded slightly; in the centre of the cornea a small abscess had developed, but healed perfectly in a few days with local treatment.

On August 26 the exophthalmos had considerably diminished; the child was so lively that he could hardly be kept in bed; the temperature had been normal for five days. The spinal fluid was only faintly opalescent, cells 10-13. We stopped further treatment.

On September 5 the child left the hospital. The right upper eye-lid was still a little swollen with slight ptosis. No exophthalmos. In the centre of the cornea a faint macula was visible. The fundus was in perfect condition. Visual acuity could not be exactly determined, but was apparently good.

At a re-examination on November 2, apart from persistent drooping of the upper lid of the right eye (4 mm.) and a small paracentral macula the size of a pinhead, the eyes were in good condition.

On November 21, 1948, we enquired after the little boy's condition and were told by his mother that he was perfectly well, that he was developing splendidly, and that the right eye-lid was no longer drooping.

Case 2.

N. I., a girl aged 18 years, applied for admission to the hospital on May 19, 1948. Her father said that three weeks previously a furuncle had developed on the right side of the girl's forehead, which had healed in a few days after having been opened by a doctor. Ten days before the girl was admitted to the hospital, another furuncle had developed underneath the first one; the doctor again opened and drained it, and prescribed two tablets of sulfamethylthyasol four times daily. In spite of this, the girl's condition did not improve, she became feverish and her right upper eye-lid started swelling.

The patient's condition when admitted to the hospital on May 19, 10 a.m.: a rather thin, languid girl, perfectly conscious; temperature 102·2° F., pulse full,

FIG. 1.—Thrombophlebitis of the cavernous sinus fully developed. The two incisions on the right side of forehead clearly shown.

slightly accelerated. V.A. right eye 5/10, left eye 5/8. The lids of the right eye were considerably swollen and bluish. Conjunctiva chemotic to a high degree, veins filled, tortuous. Exophthalmos about 1·5 cm. Normal fundus. On the left side only a slight swelling of the eye-lids was visible. The diagnosis was *retrobulbar phlegmon, incipient cavernous sinus thrombophlebitis.*

We immediately started penicillin treatment—20,000 units every three hours intramuscularly—as well as 2 tablets hexamethyl-enetetramine four times daily and a moist dressing locally. At 5 p.m., when the patient had already been given 3 doses of 20,000 units of penicillin, her condition became worse. The exophthalmos of the right eye increased, and a similar condition began to develop on the left side. The patient became somnolent and her temperature rose to 103° F. We were faced with the classical symptoms of thrombophlebitis of the cavernous sinus. At 9 p.m. the patient was completely unconscious, the back of her neck was rigid, the exophthalmos of the right eye was about 2 cm. and that of the left eye 1·5 cm.

We decided to administer penicillin intracisternally. After withdrawing 40 cc. of slightly cloudy spinal fluid which was under great pressure, we injected 20,000 units dissolved in 2 cc. of normal saline into the cisterna cerebellomedullaris.

Report on spinal fluid: albumen 120 mg. per cent. Pándy + +, Nonne-Apelt +, number of cells: 960 per mm., bacteriologically negative.

We prescribed 20,000 units of penicillin twice daily intracisternally, and 30,000 units of penicillin intramuscularly.

Next day patient was conscious and feeling better. The exophthalmos somewhat less, temperature 102° F. Therapy the same as before, but the patient was given, in addition, a daily blood transfusion of 100 cc.

After the fourth intracisternal injection of penicillin the report on the spinal fluid was: pressure reduced, cell count 312 per cc., albumen 140 mg. per cent., Pándy +, Nonne-Apelt +, sugar 0·4 mg. per cent.

On May 21, the third day of the treatment, the improvement was considerable, temperature 100·4° F. The intramuscular administration of penicillin was continued, but the intrathecal injections of 20,000 units were reduced to one daily. A blood transfusion of 100 cc. was continued daily.

May 26. The exophthalmos was definitely less pronounced on both sides. The patient opened her eyes spontaneously, her temperature was 97·7° F., her appetite was returning. The spinal fluid flowed with normal pressure. Cell count 100 per cc., Pándy +. Therapy as before.

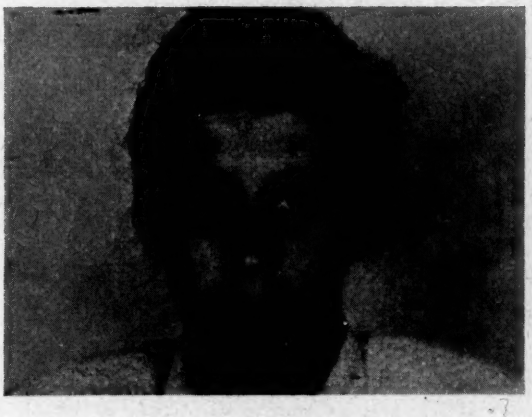

FIG. 2.—Case 2 after complete recovery.

May 28. The patient perfectly well. Report on spinal fluid: cell count 40 per cc., sugar 38 mg. per cent., albumen 20 mg. per cent., Pándy 0, Nonne-Apelt 0. No further treatment.

June 5. The patient left the hospital. No exophthalmos, both optic discs slightly hyperaemic. The right eye showed a 15° convergent squint. V.A. in both eyes 5/5.

September 27. Control examination. The girl was feeling well, had considerably increased in weight, and could carry on her normal work. The squint was better, V.A. in both eyes 5/5.

In the first case penicillin was administered in the usual way, intramuscularly, while in the second case systemic and intrathecal treatment were combined. In the first case intramuscular treatment gave satisfactory results, but in the second case, despite this method of administration of penicillin the patient developed thrombophlebitis of the cavernous sinus and, in consequence, incipient purulent meningitis.

What was the cause of this failure?

As Friedemann (1931), Elkeles (1947), and others have ascertained, the transfer of certain substances from the blood to the spinal fluid depends on the negative electric charge of these substances and on their concentration in the blood. Under normal circumstances penicillin which has a negative charge can reach the spinal fluid when adequate concentrations are present in the blood through the blood-brain barrier. These authors have also proved that when the meninges are inflamed their permeability generally increases.

Barton and others (1947), however, have found that with a normally permeable blood-brain barrier the usual 20,000 to 50,000 units of penicillin administered intramuscularly are not detectable in the spinal fluid, and that if the desired bacteriostatic concentration is to be attained 600,000 to 1,000,000 units must be given intramuscularly.

Views differ as to the question of permeability in meningitis, and thus opinions vary as to the quantity to be administered intramuscularly to produce an efficacious concentration in the spinal fluid. According to the latest data we may conclude that most of the authors think that intramuscular administration of penicillin alone is to be used only in the mildest cases of meningitis. In more severe cases, when coma has already set in, they consider it absolutely necessary to combine systemic and intrathecal treatment, as only in this way is it possible to ensure the required level of penicillin in the spinal fluid. This is proved by the wide experience of Mérei (1948) with purulent meningitis; also by two fatal cases of thrombosis of the cavernous sinus of De Jaeger and De Haene (1947), and by our second case, in which the patient became steadily worse in spite of systemic treatment, and in which

recovery was only brought about by combined intramuscular and intraspinal treatment.

The question arises whether, with intrathecal treatment, penicillin should be given intracisternally or by lumbar injection. There is no doubt that the puncture of the cistern is much easier for both doctor and patient because of its simple technique. It must also be admitted that penicillin which reaches the cisterna cerebello-medullaris is more efficacious than that given by lumbar puncture. (White and others, 1945). Apart from this we have to consider the possibility of an obstruction of the spinal canal, a complication which does not matter when penicillin is administered by intracisternal puncture. This method, however, carries with it some danger because of the risk of restlessness on the part of the patient. Therefore most doctors resort to a lumbar puncture when there is no immediate danger of a spinal block.

According to the published data a daily dosage of 20,000 to 40,000 units administered intrathecally is the quantity required to produce a satisfactory bacteriostasis in the spinal fluid, without causing great inconvenience to the patient. Too large quantities are apt to cause headache, vomiting, and paralysis. They must therefore be considered harmful.

Blocking of the spinal canal may be caused either by obturation or by adhesions. It is characteristic of the former that when a lumbar puncture is performed the spinal fluid is dense and sticky and flows slowly, and the spinal fluid is so viscous that it may impair the circulation or even stop it. An obturation block occurs at the onset of meningitis; the adhesion block, due to fibrin, tends to occur at a later stage, during the process of recovery. With thrombophlebitis of the cavernous sinus, patients usually get adequate medical treatment at an early stage of the illness because the rapidly developing exophthalmos causes anxiety to the patient's family; therefore purulent meningitis is forestalled by treatment. In these cases there is no danger of an obturation block.

Both our patients were given microtransfusions. As is known, their object is to bring immune substances, active haemoglobin, white and red blood-corpuscles, and serum albumen to the site of sepsis. By these transfusions we also stimulate the reticuloendothelial system to produce more antibodies and to change the pathological cytogenesis of the haemopoietic system. Naturally we used the transfusions only as an indirect aid simultaneously with daily penicillin treatment until cessation of fever.

What is the correct treatment for thrombophlebitis of the cavernous sinus? If the illness is still in the early stage, which can easily be ascertained by its well-known signs and symptoms,

and if the spinal fluid is clear or faintly opalescent with a cell count from 200 to 400, we can try intramuscular penicillin treatment alone. If, however, the patient has already developed the classic symptoms of thrombophlebitis of the cavernous sinus, only a combined systemic and intrathecal penicillin treatment can be successful. The examination of the spinal fluid then shows a cell count of 1,000 cubic mm. or more, but is bacteriologically negative. A further question is whether penicillin should be administered by the intracisternal or lumbar route? In our opinion, in grave cases the treatment ought to begin with cisternal punctures and change over to lumbar punctures after the condition has become less grave. We resorted to this method, bearing in mind that, if possible, the less dangerous method must be chosen. Penicillin is certainly more efficacious when adminstered by intracisternal injection than by the intralumbar route. (White and others, 1945.) The effect is increased by the fact that penicillin administered by intracisternal injection is eliminated much more slowly than that given by the intralumbar route, so the bacteriostatic level of penicillin in the spinal fluid is maintained for a longer time. In view of the risks of intracisternal punctures in patients who do not keep absolutely still, we think that these should only be carried out in the first stage of a serious case.

We give below our dosage of intrathecally administered penicillin. We injected 20,000 units twice daily into the spinal fluid as long as the serious symptoms persisted, later only 20,000 units once daily. This corresponds to the data given in the literature, most authors considering 20,000 to 30,000 units daily the correct dosage with meningitis. As, however, according to Mérei (1948), normal saline, when injected into the spinal fluid, may cause headache, convulsions, etc., it is advisable to administer penicillin by dissolving 10,000 units in 1 cc. normal saline, further diluted with the spinal fluid in the syringe.

It is also very important to know when penicillin treatment should be stopped. De Jaeger and De Haene believe that in fatal cases penicillin treatment was stopped too early. We observed this in our first case. When, however, after a relapse, we restarted energetic penicillin treatment the patient recovered. Penicillin treatment is discontinued when the report on the spinal fluid shows a reduction in cell count. It should not be discontinued before the cell count is below 100. Then, naturally, the patient has had no fever for several days, and the eye symptoms are subsiding.

Besides the general treatment mentioned above and a daily microtransfusion of 100 cc., we gave the patients sulphonamides in short shocks. It is important to supply the need for vitamin C

and fluids. A protective bandage should be applied to the eyes in order to avoid abscesses of the cornea which may develop while the patient is unconscious.

Thus it is evident that the treatment of thrombophlebitis of the cavernous sinus is a serious task for the ophthalmologist. He can only carry it out by most careful observation and efficient co-operation with other specialists. If treatment is begun in time this disease is now curable without leaving any traces, although up to the present time every case of thrombophlebitis of the cavernous sinus has ended fatally.

Summary

Thrombophlebitis of the cavernous sinus, which has always been fatal hitherto, is curable by a combined systemic and intrathecal penicillin treatment.

We believe that systemic treatment alone should only be attempted at an early stage of the illness, when the cell count in the spinal fluid is from 200 to 400. In more advanced cases, only a combined treatment will give satisfactory results.

Although intracisternal injections are much more effective than intralumbar treatment, they should only be resorted to at the beginning of severe cases (with unconsciousness, etc,) because of the patient's restlessness. When, however, the grave symptoms have disappeared, intralumbar treatment should be given.

The dose of penicillin to be injected into the spinal fluid should be 20,000 units twice daily, 10,000 units penicillin dissolved in 1 cc. normal saline which must be further diluted with the spinal fluid contained in the syringe.

Penicillin treatment ought to be stopped only when the cell count in the spinal fluid is below 100.

Besides the intrathecal treatment, 20,000 units of penicillin are given intramuscularly every three hours.

Apart from penicillin treatment a blood transfusion of 100 cc. is given daily, and the resisting power of the body is supported in every possible way.

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IMMUNOLOGICAL SIGNIFICANCE OF DEMYELINATION OF MEDULLATED NERVE FIBRES OF THE EYE*

BY

EMANUEL ROSEN

Newark, N.J.

A VERY important case report by W. A. Anderson (1942) has come to my attention. The patient, aged 60 years, showed marked medullated nerve fibres of his fundi completely covering the edge of each disk. In this case an upper respiratory infection was followed by an optic neuritis with disappearance of the medullated nerve fibres. Anderson stated that there was a change in the medullated nerve fibres secondary to an optic neuritis, which he had never seen before and which was not without interest, as it revealed the effect of an inflammatory change on the medullation of the nerve fibres.

In the spring of 1948, I saw a case not unlike that described by Anderson. The patient was a 42-year-old coloured male whose chief complaint was loss of vision of several days' duration associated with headache involving the mid frontal area. In the past history it was learned that the patient was employed by the city as a " snow-shoveller ". He had suffered from various colds and a persistent cough which had not disappeared. His present illness probably dated back about three weeks before admission to hospital, at which time he noted burning, lacrimation, fatigue, and inability to read for very long. He was admitted directly from the railroad station where he had fallen asleep for two hours and was unable to see with either eye when he awoke. The positive physical findings included an element of drowsiness and a suggestion of inability to concentrate. His pupils were widely dilated and failed to react to light. There was no restriction of motility. The conjunctiva and cornea were normal. There was no disturbance of aqueous, lens, or vitreous. Tension was recorded as 9 (Schiötz) in each eye. The pathological findings were restricted to the fundi, the picture being more pronounced in the left eye than in the right. In each fundus there appeared to be an area of neuroretinitis in the region around the disk, with the circumpapillary retinal tissue being whitish, oedematous, and fibrillated. Shining through this hazy retinal oedema were two whitish masses, in each of which appeared specifically to be groups of medullated nerve fibres such as might be seen through dense

* Received for publication December 16, 1948.

clouds. By focusing carefully upon these areas the characteristic fibrillations and striations seen in medullated nerve fibres of the fundus could be ascertained. The entire picture was one of retinal oedema restricted to this area of usual location of medullated nerve fibres above and below the disk.

The veins were neither full nor tortuous; the arteries on the other hand appeared lighter and narrower than usual. In some areas there appeared a suggestion of beading or connective tissue cuffing of the arterioles. In the temporal area of the right fundus there were several old round globular exudative foci and some pigment nearby. The maculae looked radiolucent and their glow seemed to be emphasized by a change in the perimacular colour.

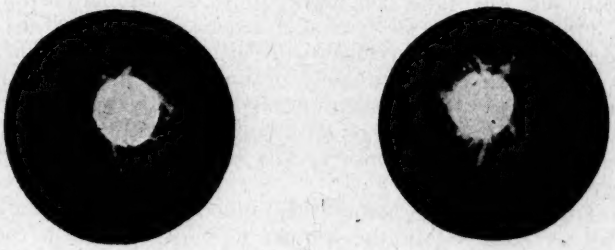

FIG. 1.—Fundus—right and left, showing optic atrophy.

The spinal fluid showed 75 mg. protein per 100 cc. The blood showed a white count of 2,900 with 50 per cent. lymphocytes.

The patient was kept under observation for several months. The oedema gradually subsided and left an atrophy in its wake (see Fig. 1). There was some slight visual improvement so that the patient could discern large objects in the periphery, but he was still unable to get about to any degree when he was transferred to a veterans' hospital.

Some months ago while studying the problem of post-vaccinial encephalitis, I expressed the view that, through study upon patients whose eye grounds showed medullated nerve fibres, the solution to the problem of the aetiology of the demyelinating encephalitides, especially multiple sclerosis, and the acute exanthemata, might be greatly facilitated. To the ophthalmologist and possibly also to the neuropathologist this statement might seem somewhat unconnected, and so I should like to clarify this suggestion through the introduction of some basic immunologic principles as yet little known. Morrison (1947) reported

upon a disseminated encephalomyelitis experimentally produced by the use of homologous antigen. Morrison concluded that encephalomyelitis may be experimentally produced in laboratory animals by the repeated injections of heterologous brain antigen. He furthermore stated: " Without belaboring this point unduly, it is becoming apparent that there are many features of histologic similarity in the various stages of progress of multiple sclerosis, Schilder's disease, neuromyelitis optica, and post-infectious and post-vaccinial encephalomyelitis." It also has been shown that there is a certain similarity between these demyelinating diseases, on the one hand, and the experimentally produced encephalomyelitis reported in his study, on the other. The number and variety of histological reactions in the brain are of necessity limited, and the same conclusion must be assumed within the eye; and if the process is one of reaction to virus it is likely to be the same for all viruses with little or slight modification. And if such an eye fortunately or unfortunately has a ring of medullated nerve fibres surrounding the optic nerve, and if a reaction is taking place upon white matter within the brain, what better place is there to observe this site of reaction than in the eye ground?

Noran, Baker, and Larson (1947) noted that the morphological alterations observed in the human nervous system in cases of " pneumonic encephalitis " and in experimental lesions are essentially identical. This suggested that both are the result of the same process, namely the introduction of some product from the lung into the blood stream which facilitates blood clotting, and that these pathological observations are additional proof that the cerebral complications of pneumonia may result from a disturbance of the clotting mechanism. This experimental reproduction of the lesions of so-called " pneumonic encephalitis " clearly indicates that pneumonitis liberates some product from the patient's lung which, in turn, produces an intravascular clotting in the cerebral vessels. When one considers the frequency of infections of the respiratory tract, and the possibility that a patient may be affected by a break-down of his own lung tissue, it becomes apparent that this phenomenon may have implications of significance in other conditions. There are many examples which illustrate the importance of the lung in cases of encephalitis, *i.e.*, Krieder (1943), Fyfe and Fleming (1943), Wohlwill (1928) and Ansell (1948).

Since most of the acute exanthematous diseases of viral aetiology have their portal of entry *via* the upper or lower respiratory system, and since the organism may act upon and produce certain changes which subsequently influence the development of an encephalomyelitis with predilection for the white matter, and since antigenic

white matter may be visualized in the ocular fundus if it fortunately contains the anomalous medullated nerve fibres, the importance of these medullated nerve fibres is at once quite evident.

In restudying Professor Anderson's case it seems evident that a patient whose vision was normal (and with medullated nerve fibres) suffered from a pharyngeal and then a pulmonic infection, and then developed an optic neuritis with eventual optic atrophy and complete disappearance of the medullated fibres. This seems quite like the experimental respiratory changes which subsequntly produce a demyelination of the brain and optic nerve with its medulated nerve fibres.

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BOOK NOTICE

Year Book of Eye, Ear, Nose and Throat. Edited by D. VAIL and S. J. CROWE. Year Book Publishers, Chicago, 1949. Illustrated. Pp. 580. No price given.

The ophthalmological section of the 1949 Year Book of Eye, Ear, Nose and Throat is edited by Derrick Vail, the previous editor, Louis Bothman, having died. The lay-out of the book corresponds to that in previous editions, the different ocular tissues—lids, orbit, conjunctiva, cornea, uveal tract, lens, retina, choroid, and optic nerve—being treated seriatim. There are full sections on glaucoma, refraction, motility, neurology, therapy, and surgery, and a miscellaneous chapter dealing with conditions not easily classified. The book contains a résumé of the more important articles on each subject and, the editor's choice being remarkably sound, provides a very ready and readable means of keeping abreast of the more important recent advances in ophthalmology.

"KNOB" AT THE PERIPHERY OF DESCEMET'S MEMBRANE*

BY

ARNOLD LOEWENSTEIN

Tennent Institute for Ophthalmology, University of Glasgow. Director, Prof. Riddell.

As is well-known the peripheral end of Descemet's membrane in antero-posterior sections usually tapers to a point. This is shown clearly at *a* in Fig. 1. What has not been previously described

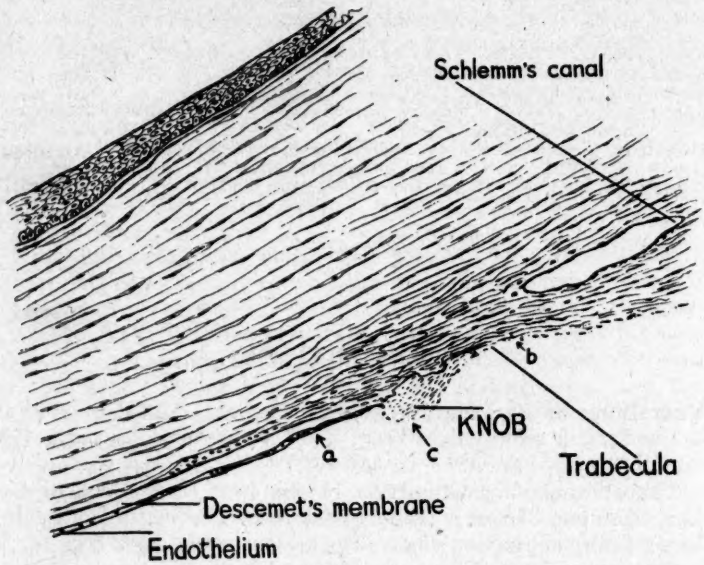

FIG. 1.

however is that the usually flat tissue between *a* and the trabecula (*b*) may project backwards as a knob (*c*). This swelling is granular and does not contain cells (Figs 2 and 3).

Here this knob-like bulge has been demonstrated in five eyes, three knobs were normal and two were malignant melanomata. Generally, the five cases (Figs 2-6), show the different structure of the knob, the prominent zone in the area of the gap.

We understand that the aqueous fluid enters the gap and reaches the posterior lamellae. The aqueous does not filter the posterior

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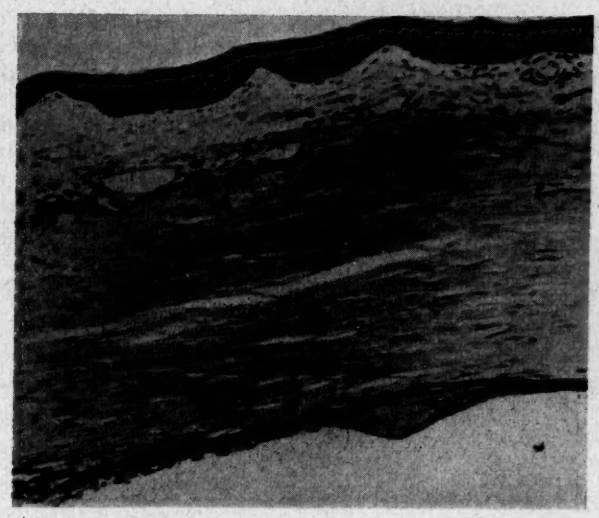

FIG. 2.—Prominent Schwalbe's ring. The Knob is bulged without lamellae. Some dark nuclei in the endothelium. (H.E. 300×.)

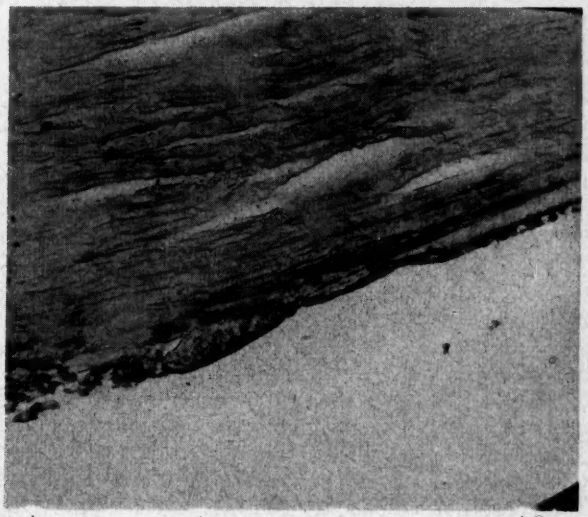

FIG. 3.—Malignant choroidal melanoma. Prominent Schwalbe's ring. Note the granular structure of its tissue. (Azanst. 300×.)

lamellae as the end of Descemet is completely intact (Fig. 1, *a*). On the other hand, the aqueous passes the meshwork of the trabeculae and finally reaches Schlemm's canal (Fig. 1, *b*). The important gap is between *a* and *b*. In five sections the tissue in the gap shows the swollen knob as at *c* in Fig. 1 in the prominent area.

The aqueous enters the gap and may produce different reactions:

(1) In some eyes the posterior lamellae in the gap may remain

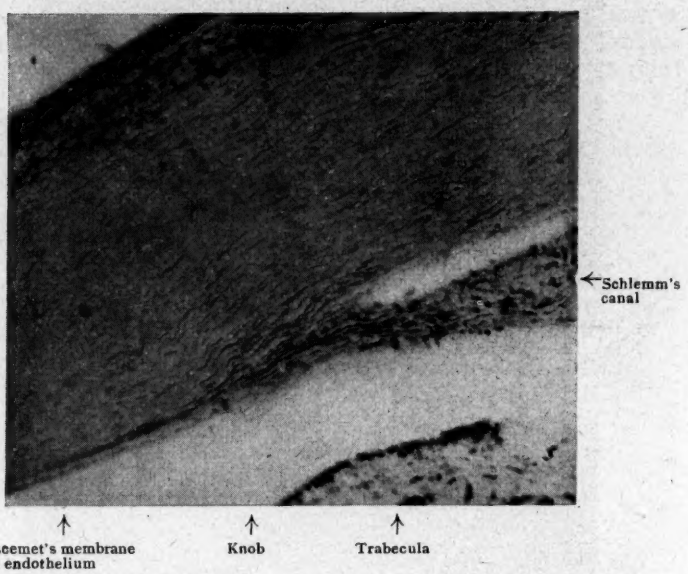

FIG. 4.—Typical Knob between end of Descemet's membrane and Trabecula. (H.E. 300×.)

flat and form the white ring of the excised eye seen with the slit-lamp. This is identical with the white ring of Schwalbe, and is well known in clinical gonioscopy.

(2) In other eyes the posterior lamellae may be swollen to form the prominent white ring seen with a high-power slit-lamp.

It is not easy to prove the histological appearance of Schwalbe's ring in section. It seems that the aqueous fluid does not produce characteristic changes detectable on staining. On the other hand, the prominent knob is perfectly seen in Figs 2-4.

We assume the aqueous enters the gap between *a* and *b* and swells the posterior lamellae to form the whitish ring. The whitish ring was demonstrated at the Oxford Congress (Loewenstein, 1948), *en face* and in profile in Donald's original picture. The

whitish ring in the slit-lamp and the prominent knob may be identical. A multiple congenital anomaly of the eye discussed by A. J. Ballantyne (1949) from another point of view, shows a prominent nodule in the area of the gap between the end of the Descemet and the trabecula (Fig. 5).

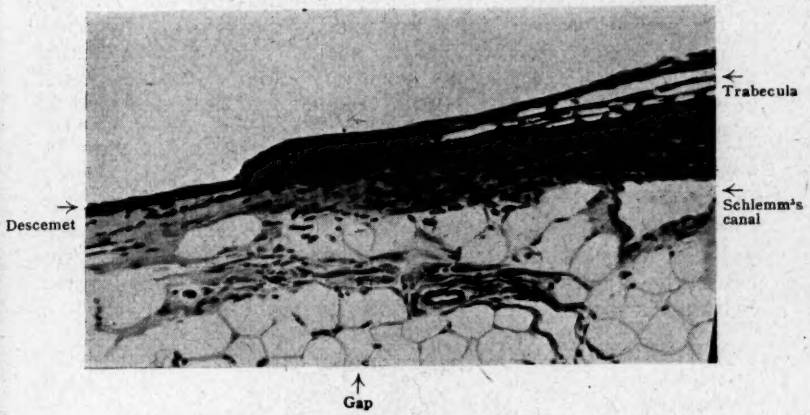

FIG. 5.—Congenital anomaly. Nodule between end of Descemet's membrane and trabecula. (Van Giesson. 300×.)

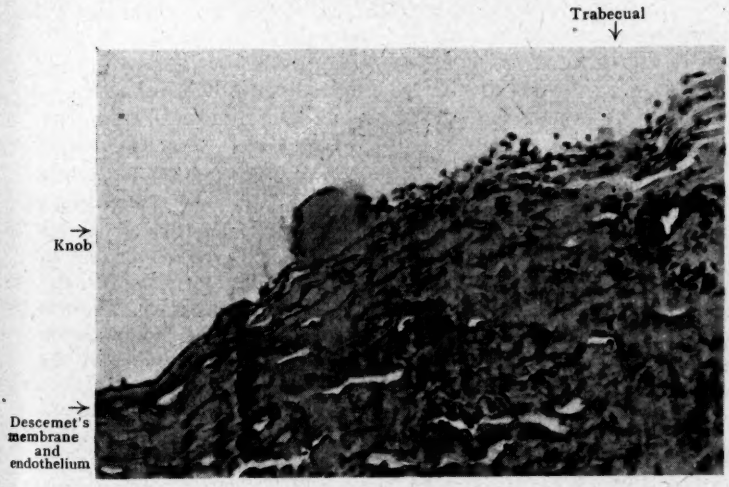

FIG. 6.—Knob-like bulge in area between Descemet's end and trabecula. Mustard gas traumatism. (H.E. 300×.)

Both processes seem to be physiological. But some pathological changes may occur. I have observed a case of corneal degeneration in an eye injured by mustard gas in the first world war about 30 years ago. (The case is to be published by Dr. Thakore.) The corneal lamellae were intensely swollen and dilated, with many huge vessels surrounded with lymphatic infiltration. A knob bigger than in the other cases was prominent (Fig. 6). The gap of the area between *a* and *b* was exactly the same. This knob contained cloudy tissue without any nuclei. I am not sure whether the nodule in Fig 6 had the same physiological characteristics, in which case it might be that the lamellae had been damaged by some chemical or other influence.

Summary

The changes in the whitish ring of Schwalbe seen in the excised eye with the slit-lamp have been explained anatomically. In five cases the typical prominent knob has been demonstrated. Schwalbe's ring and the knob appear to be the same.

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NOTES

Toronto

THE Department of Ophthalmology in the University of Toronto has received a grant from the Ontario Provincial Department of Health through funds provided by federal grant for research work on the prevention of blindness from glaucoma. This work will be done under the direction of Dr. T. H. Hodgson in the Banting Institute, Toronto General Hospital, and other University teaching hospitals in Toronto. The initial grant was $8,200. It is proposed that the research work will extend over 3 to 5 years.

THE ALL-TANTALUM CUTLER UNIVERSAL INTEGRATED IMPLANT*

A modified technique for its introduction: Case Reports

BY

JAMES R. HUDSON

London

THE gradual development and improvement of orbital implants, designed to impart to the ocular prosthesis a full range of movement, has been accompanied by the repeated disappointment of the rejection of the implant by the orbital tissues.

From the old types of buried implants—glass, ivory, and more recently plastic, globes—there has developed the integrated implant, in which the front surface is left exposed for direct contact with the back surface of the prosthesis (Reudemann, 1945; Hughes, 1948).

The Cutler ring implant (Cutler, 1947), of which a limited number has been used in Great Britain, has been followed by the " universal " type, a plastic ball of which the anterior convex surface is covered with a fine mesh of tantalum wire (Cutler, 1949). There is now in use in Great Britain an all-tantalum implant, in which the solid plastic ball has been replaced by a hollow tantalum shell. The advantage of this most recent type is that, as far as is known, tantalum is completely inert in the tissues, whereas cases of sensitivity to plastic materials have been recorded.

The " universal " type of implant was originally designed to be introduced following eviscero-enucleation, in which a scleral ring is left *in situ* with the four recti attached. The implant is introduced through a radial incision in the conjunctiva and Tenon's capsule, and is then sutured to the scleral ring (Cutler, 1947).

It is, however, relatively infrequently that an eye is removed in circumstances in which an implant might be used, when an evisceration is to be preferred to an enucleation. The former operation is usually reserved for cases of panophthalmitis, in which division of the optic nerve in the presence of infection is better avoided. In such instances, the introduction of any type of implant would probably be accompanied by considerable tissue reaction.

The commoner indications for enucleation include malignant neoplasms, injuries with gross disorganization of the globe, and secondary glaucoma. In all these cases complete removal of the eye is desirable.

Having used the all-tantalum implant on two or three occasions, and having observed that there is a tendency for the structures attached to the tantalum wire slightly to retract, I devised the method about to be described, in which the scleral ring of the

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original operation as described by Cutler (1947) is replaced by a ring of muscular tissue. This is designed to make it physically difficult for the implant to be extruded. Even if the muscle is replaced by fibrous tissue at a later stage, it will continue to serve its function.

The operation is carried out under general anaesthesia, 1 in 1,000 adrenaline drops having been instilled into the conjunctival sac

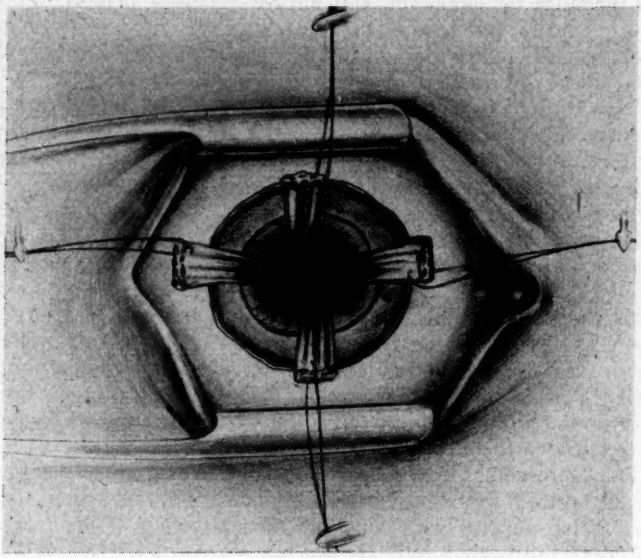

FIG. 1.—The socket immediately after the removal of the globe, showing catgut sutures through the tendons of the four recti.

pre-operatively, and 3 minims of 1 in 1,000 adrenaline in 1½ cc. of saline given by retrobulbar injection.

A Lister's speculum is used. The conjunctiva is divided around the limbus, and separated back by blunt dissection, avoiding as far as possible disturbance of Tenon's capsule. Each of the recti is then cleaned sufficiently to allow of easy identification of the tendon, and a single-ended 4/0 chromic catgut stitch on a No. 6 needle is passed through one side of the tendon, and looped through to secure a good hold. Care is taken not to clean the muscle belly. The muscles are then divided at their insertions, and the catgut retaining stitches are held back out of the way by clips (Fig. 1). It is convenient to use mosquito forceps for the vertical recti, and " bulldog " clips for the horizontal muscles, or some other simple method to avoid confusion at a later stage. The oblique muscles are next divided, and the eye is excised.

Haemostasis is secured as far as possible at this stage of the operation, but there is usually very little bleeding when retrobulbar saline and adrenaline solution have been used.

A double-ended No. 1 silk suture on No. 4 needles is now introduced into the tantalum mesh, parallel with and slightly behind its front edge. The implant is then dropped into place, and the

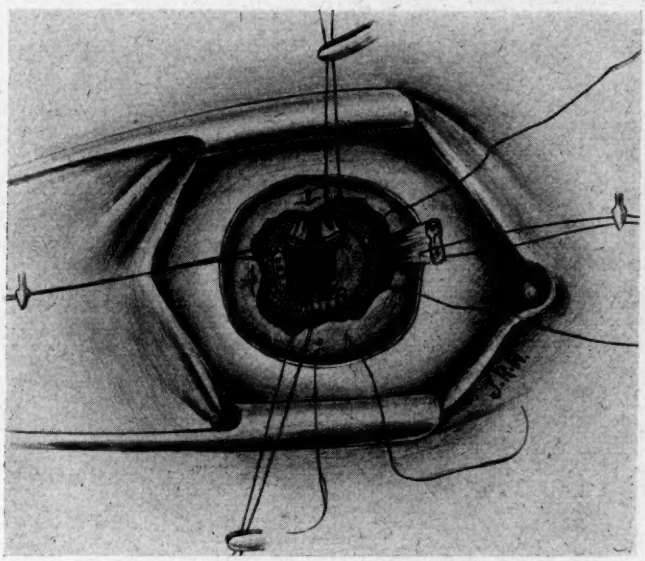

FIG. 2.—This diagram shows the internal rectus turned back, with its retaining suture of No. 1 silk threaded through the tantalum mesh. The inferior rectus has the stitch drawn through the belly of the muscle and the overlying Tenon's capsule.
The external rectus has the suture tied and cut. The superior rectus shows the appearance after dividing the tendon in the line of its fibres, the medial division of the muscle being held aside by the catgut stitch placed in position at the beginning of the operation.

two ends of the silk stitch are passed through the belly of the superior rectus muscle (from its scleral to its subconjunctival surface), about 5 mm. behind the tendon, and then through the overlying Tenon's capsule. This stitch is then securely tied, and cut short. The bellies of the remaining three recti are attached to the tantalum mesh in a similar manner (Fig. 2).

The next step is to identify the tendons of the recti and to divide them in the line of their fibres, to a point just short of the securing silk stitches. Each muscle now presents two tendon slips, in one of which is the catgut stitch introduced at an earlier stage of the operation. This stitch is now passed through the mesh between its own muscle and the adjacent one, through the free slip of the

latter muscle, and finally includes the edge of Tenon's capsule between the two muscles before being tied. Each of the four catgut stitches is dealt with in a similar manner, forming on completion a continuous ring of muscle around the neck of the implant (Fig. 3).

Penicillin drops are instilled into the wound at this stage, and the conjunctiva is stitched to the front edge of the mesh. This is done with a 4/0 chromic catgut suture on a No. 4 needle, care

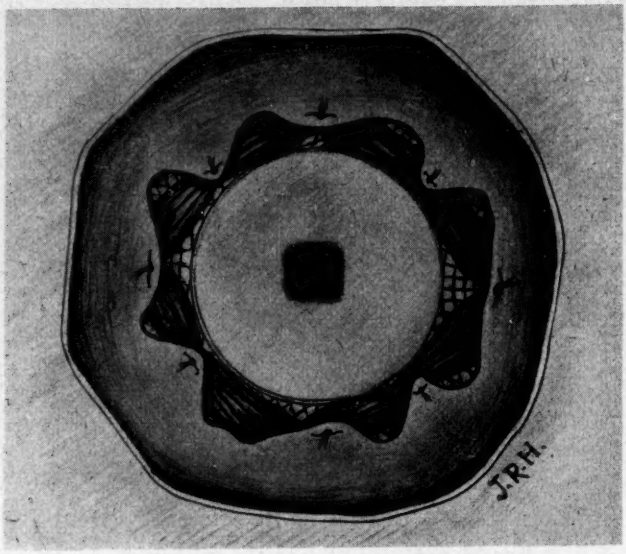

FIG. 3.—This shows the implant in position, with the four muscles sutured in position, and the catgut stitches between them holding Tenon's capsule and neighbouring divisions of the recti on to the wire mesh.

being taken to invaginate the margin of the conjunctiva at the same time (Fig. 4).

The operation is now complete, and the socket is carefully packed with tulle gras to maintain gentle pressure between the closed lids in front and the implant behind. The lids may be loosely stitched together to ensure that the packing remains in place.

The eyes are double-padded, the outer dressing being changed after 48 hours. At the first dressing, the unoperated eye may be left unpadded if the socket of the other side is comfortable. If the movement of the eye should cause discomfort in the socket, then double padding is continued for a period of up to 7 days. For three days following the operation intramuscular penicillin is given in the dosage of 200,000 units 6-hourly.

The tulle gras is removed from the socket after seven days, and

the retainer shell of plastic material is immediately put in position. This is not removed except for fitting the prosthesis. The socket is irrigated three times a day for a few days with 1 in 8,000 oxycyanide of mercury, and thereafter once or twice daily with saline lotion. The retainer shell is not removed for this purpose.

After the final fitting, the prosthesis is left in position continuously unless there is some positive indication for its removal.

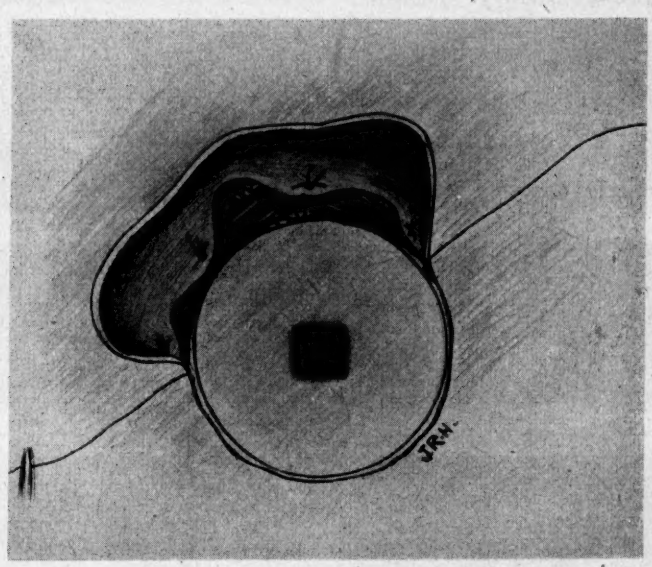

FIG. 4.—The continuous catgut suture for the conjunctiva has been partly completed.

Any slight discharge can be dealt with by irrigation, or by the use of 30 per cent. albucid drops, leaving the prosthesis in place.

The advantages of the operative technique described are these:

1. It is relatively simple.
2. The implant is retained by a complete muscular ring. Even if this becomes converted into fibrous tissue at a later stage, it will still fulfil its function.
3. There is a relatively large surface area of each muscle in contact with the tantalum mesh.
4. There are no stitches to be removed after the operation.
5. Packing the socket prevents chemosis and also the appearance of bruising during the first week, after which the retainer shell serves the same purpose.
6. Double padding allows some consolidation of the tissues attached to the implant before movement is permitted.

FIG. 5.—Photographs of Case 1.

FIG. 6.—Photographs of Case 2.

Case histories.—Included in these is one (Case 1) in which the plastic cylinder type of implant with gold ring was used. In Case 2 the earlier rather heavy all-tantalum implant was used, and in the remaining cases the most recent hollow all-tantalum implant. Cases 5 and 6 were the first in which I used the technique described.

Case 1. J. G. Female—aged 21 years. Right excision for melanoma of the choroid. Operation on 6.7.49. Good movements. (Fig. 5.)

Case 2. R. J. Male—aged 25 years. Right excision following rupture of globe due to injury. Operation on 13.7.49. There is slight retraction of the tissues around the front margin of the tantalum wire in this case, but the implant appears to be firmly in position. Good movements. (Fig. 6.)

Case 3. T. G. Male—aged 41 years. Left excision for blind, irritable eye—history of injury 20 years previously. Operation on 16.8.49. In this case marked retraction of the tissues occurred above the implant, and there was little upward movement. The patient was re-admitted and the superior rectus and surrounding tissues were re-attached to the implant. Operation 7.9.49. There is still some limitation of upward movement. It was on account of the failure in this case that the modified technique described in the foregoing paragraphs was devised.

Case 4. M. B. Female—aged 4½ years. Left excision following penetrating injury with an arrow. Operation 23.8.49 (11 days after injury). Movements good. Some retraction of tissues around front margin of implant.

Case 5. I. M. Female—aged 52 years. Left excision for melanoma of choroid. This was the first case in which the modified technique was used. Operation 13.9.49. Good movements—plastic shell placed in socket on 8th post-operative day.

Case 6. P. P. Male—aged 12 years. Right excision following penetrating wound and retention in globe of lead airgun pellet. Operation 11 days after injury, which occurred on 6.9.49. In spite of some chemosis before the operation, the socket was very satisfactory when dressed 7 days after the operation. Retainer shell put in immediately after removal of dressing. Good movements.

Four further cases have been operated upon more recently than those described, and the results have been encouraging.

Summary

A technique for the introduction of the Cutler universal implant (all-tantalum), following enucleation of the eye, is described. The author considers that, by the use of the tendons of the recti to form a complete ring around the neck of the implant, attachment of the muscles to the tantalum mesh is more secure, and the possibility of later extrusion of the implant is greatly lessened.

I should like to express my thanks to members of the staff of the Moorfields Branch of the Moorfields, Westminster and Central Eye Hospital, for their permission to operate on the cases described, and for their kindness in allowing me to publish the results. I should also like to thank Dr. Peter Hansell of the Department of Medical Illustration, Institute of Ophthalmology, for the photographs of Cases 1 and 2.

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RIBOFLAVIN DEFICIENCY WITH OCULAR SIGNS: REPORT OF A CASE*

BY

C. R. S. JACKSON

From the Nuffield Laboratory of Ophthalmology, Oxford

IN view of its comparative rarity in Great Britain it seems justifiable to report a case which appeared to be one of riboflavin deficiency presenting ocular symptoms.

Case Report

A married woman, 52 years old, first seen September 1, 1948, was complaining of epiphora and a slight irritation of both eyes, particularly the right, with some photophobia. The illness was of some three months' duration, though she said she had had recurrent attacks of "sore eyes" for many years. The present attack seemed to have started after a long train journey.

The visual acuity was right 6/6, left 6/36, the left eye having been known for some time to be amblyopic. Both eyes looked irritable and the conjunctiva was slightly congested. There was no evidence of intra-ocular inflammation but, with the slit-lamp, superficial vessels could be seen extending on to the cornea from the limbal plexus. These vessels were very thin but contained blood and were arranged in a fairly regular manner all round the periphery of the cornea and directed towards the centre. They were mostly straight and anastomosed with each other, forming attenuated arcades. There were no other abnormalities.

The picture of the abnormal corneal vessels was so like that seen in ariboflavinosis as described originally by Sydenstricker and others (1940) and later by Gregory (1943), Ferguson (1944), and Mann (1945), that a provisional diagnosis of riboflavin deficiency was made. The possibility of an infective conjunctivitis was also considered, but bacteriological examination of the conjunctiva showed no pathogenic organisms.

The patient was given no treatment apart from riboflavin 9 mg. by mouth daily. Unfortunately she did not attend again for a month but her non-appearance was apparently due to the improvement in her condition, for she said that her eyes seemed to be entirely normal after about nine days on riboflavin, all grittiness and photophobia disappearing. Improvement had been noticed within a few days of starting to take the vitamin.

When next examined, September 27, 1948, the abnormal corneal vessels had undergone very considerable regression and those still visible contained little blood. There was no congestion of the conjunctiva.

The patient was asked about her diet. She was a hard-working housewife with a husband and son out at work. She admitted that she was not particularly anxious about what she herself ate and liked "to give as much as possible to the men". Cups of tea with bread and butter seemed to figure largely in her diet. When it was put to her that perhaps she was not getting enough to eat, she agreed that, although she usually had something of what she cooked for the men, her portion was never very large.

Twelve months after treatment with riboflavin she wrote, "I have not been troubled with sore eyes since my visit in October last. I have followed your advice about diet."

Discussion

The response to riboflavin was so striking that there seems no doubt that the ocular signs in this case were due to deficiency of the vitamin. It has been pointed out previously (Mann, 1945)

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that a distinction must be drawn between the normal limbal capillary plexus and the appearances of new superficial vessels on the cornea, and that failure to appreciate this distinction may be the cause of the large numbers of cases of this condition in some published reports (Kruse and others, 1940; Frandsen and Lundh, 1941; Tisdall and others, 1943). The present case was examined with this point in mind.

At no time in the course of the illness did the patient show any of the cutaneous manifestations of riboflavin deficiency. She did, however, admit to some feelings of excessive tiredness and lack of energy which may perhaps have been part of the same picture.

It is interesting to note that a recent paper by Das Gupta (1949) suggests that this type of corneal vascularization may not be the only way in which riboflavin deficiency may show itself in the eye. He describes a case of parenchymatous keratitis in which corneal opacity was unaccompanied by vascularization. The condition resolved completely after injections of riboflavin (10 mg. daily for 78 days).

A very similar but much more severe case of the type described here has been reported by Stern (1949). His patient was a man aged 38 years in whom the condition had been precipitated by trauma. Stern suggests that, the metabolic activities of injured corneal epithelium being greater than those of the normal, it can not be provided with sufficient respiratory enzyme in the absence of adequate riboflavin. The picture of corneal vascularization and unhealthy epithelium may therefore be " conditioned " by superficial injury and may develop on top of what has previously been a subclinical deficiency of the vitamin.

Stern suggests that three conditions should be fulfilled before the diagnosis of ariboflavinosis is made. There should be (i) a history of inadequate intake of the vitamin over a long period, (ii) a low riboflavin level in blood or urine, (iii) an obvious response to treatment with riboflavin.

Although the disappearance of photophobia and regression of the abnormal vessels as a result of treatment may be very striking, it seems that the improvement in visual acuity may be disappointing in long-standing cases owing to the persistence of corneal opacities.

I am grateful to Mr. A. C. L. Houlton for permission to publish this case.

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THE CARDINAL POINTS IN CORRECTED AMETROPIA*

BY

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New York

IN hypermetropia the clear image of a distant object falls behind the retina; in myopia the clear image of a distant object falls in front of the retina. The correcting lens, convex or concave, does not alter the position of the retina, but alters the position of the clear image, placing it on the retina. The clear image formed by the optical system of the eye is best known as the optical image. Moving the optical image from behind, or in front of, the retina on to the retina is accomplished primarily by a movement of the cardinal points of the eye.

If the correcting plus lens is placed so that its second principal point is at the anterior principal focus of the eye, the combined

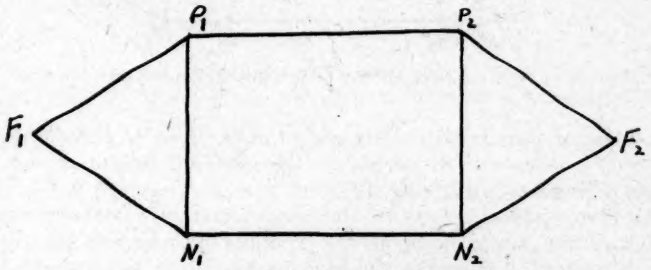

FIG. 1.—The cardinal points of the uncorrected eye.

power of eye and lens is the same as that of the eye alone. Similarly, if the correcting minus lens is placed so that its second principal point is at the anterior principal focus of the eye, the combined power of eye and lens is the same as that of the eye alone. The significant optical changes which these lenses produce is a shifting of the cardinal points of the eye. These shifts can be diagrammatically shown and remembered by a horizontally placed Benzene ring.

Let F_1, F_2, P_1, P_2, N_1, N_2 (Fig. 1) represent the cardinal points of the uncorrected eye. These points are the two principal focal points, the two principal points, and the two nodal points.

Dedicated to Professor Josef Meller on his 75th birthday.

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Distances represented by opposite parallel lines are equal: thus $P_1 F_1$ (the first principal focal length) equals $N_2 F_2$; $P_2 F_2$ (the second principal focal length) equals $N_1 F_1$; $P_1 P_2$ (the distance between the principal points) equals $N_1 N_2$ (the distance between the nodal points); $P_1 N_1$ equals $P_2 N_2$ and represents the " equivalent " radius of the system, that is the radius of the single refracting surface which can replace the system.

In Fig. 2, let F^c_1, F^c_2, P^c_1, P^c_2, N^c_1, and N^c_2 represent the cardinal points after correction, *i.e.*, of the combined system of lens and eye. If a plus lens is used for correction in

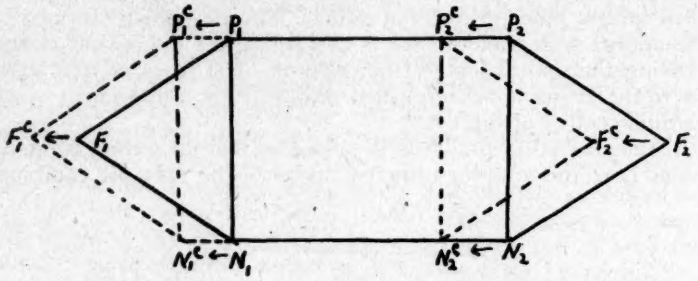

FIG. 2.—Pascal's schema for the movements of the cardinal points in corrected hypermetropia.

the position previously mentioned, the position of the combined cardinal points with reference to the cardinal points of the eye alone is indicated in the figure.

All the cardinal points of the uncorrected eye move forwards (think of the cornea being to the left and the retina to the right). The direction of movement is indicated by little arrows. P_1, N_1, and F_1 all move the same amount. $P^c_1 F^c_1$ is parallel to $P_1 F_1$. So is $N^c_1 F^c_1$ parallel to $N_1 F_1$. The extent of this movement depends partly on the thickness of the correcting lens and is equal to the distance between the principal points of the lens. P_2, N_2, and F_2 also move an equal amount, ordinarily a greater distance than the movement of the first set of cardinal points. $P^c_2 F^c_2$ and $N^c_2 F^c_2$ are parallel to $P_2 F_2$ and $N_2 F_2$. Parallelism of the focal length lines shows that the focal lengths of the combined system are equal to the corresponding focal lengths of the original system. The distance between the new principal points and the corresponding nodal points is the same as before, *i.e.*, $P^c_1 N^c_1 = P_1 N_1 = P^c_2 N^c_2 = P_2 N_2$. This is to be expected as the combined optical system has the same power as before, and the " equivalent " radius of the combined system must be the same as the equivalent radius of the original system.

The principal points are closer together as if the combined system were a " thinner " optical system. The nodal points are also closer together showing less displacement of the secondary axes. The second nodal point has moved forwards resulting in a *larger* retinal image as is the usual finding in corrected hypermetropia.

Fig. 3 shows what happens in a myopic eye with a minus lens correction. The " first " cardinal points, P_1, N_1, and F_1, move forwards; the " second " cardinal points, P_2, N_2, and F_2, move backwards. The movement of the " second " points is greater than

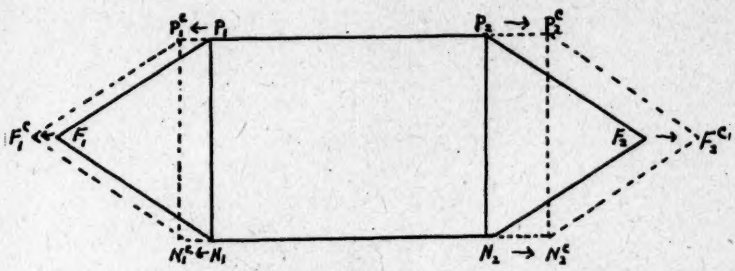

FIG. 3.—Pascal's schema for the movement of the cardinal points in corrected myopia.

the movement of the " first " points, the latter being equal to the distance between the principal points of the concave correcting lens. Here too parallelism of the lines shows that the focal lengths of the combined system are equal to the corresponding focal lengths of the original system. So is the " equivalent " radius of the combined system equal to the " equivalent " radius of the original system. The principal points are further apart as if the combined system is a " thicker " optical system.

The nodal points are also further apart, showing greater displacement of the secondary axes. The second nodal point has moved backwards (towards the retina), producing a smaller retinal image than the " basic " retinal image before correction. By the " basic " image is meant the image formed by the points of intersection of the secondary axes with the retina. The diffusion circles in the uncorrected image make the original image even larger. The resultant *smaller* retinal image is the usual finding in corrected myopia.

The Benzene ring can be used in the same fashion to visualize the movement of the cardinal points when the correcting lens is placed in a position different from the one considered in the present article.

Summary

A graphic method is presented to show visually the movement of the cardinal points of an eye occasioned by the application of correcting lenses placed in the plane of the anterior principal focus of the eye. The resultant changes in the " thickness " of the optical system, the displacement of the secondary axes, the increase or decrease in the size of the retinal image, etc., can be read off directly from the schema and more easily remembered and understood.

OBITUARY

MARCUS FINE

WE regret to announce the recent death of Marcus Fine in Johannesburg as a result of a motor accident.

He qualified from the London Hospital in 1925 and ultimately became assistant, and then senior, House Surgeon to the Royal Westminster Ophthalmic Hospital in 1927-28. He was the last House Surgeon to the hospital on its old site adjacent to Charing Cross. He obtained the D.O.M.S. in 1927, and on returning to South Africa built up a flourishing ophthalmic practice in Johannesburg, where he was later appointed Assistant Ophthalmic Surgeon to the General Hospital. When he re-visited London in 1949, he took considerable interest in the operation and orthoptic work at his old hospital.

M. L. H.